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WHITE RIVER SHALE PROJECT

FEDERAL PROTOTYPE OIL SHALE TRACTS Ua and Ub

prepared by

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June, 1983

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INTRODUCTION

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this report, "1982 Progress Report Environmental Program White River Shale Project," is to present the results of ambient environmental monitoring and reclamation research activities associated with the development of Federal Prototype Oil Shale Lease Tracts Ua and Ub located in northeastern Utah. With the exception of the water resources section, this report covers monitoring studies conducted during calendar year 1982. The water resources section is based upon the 1982 water year (i.e., October 1, 1981 through September 30, 1982).

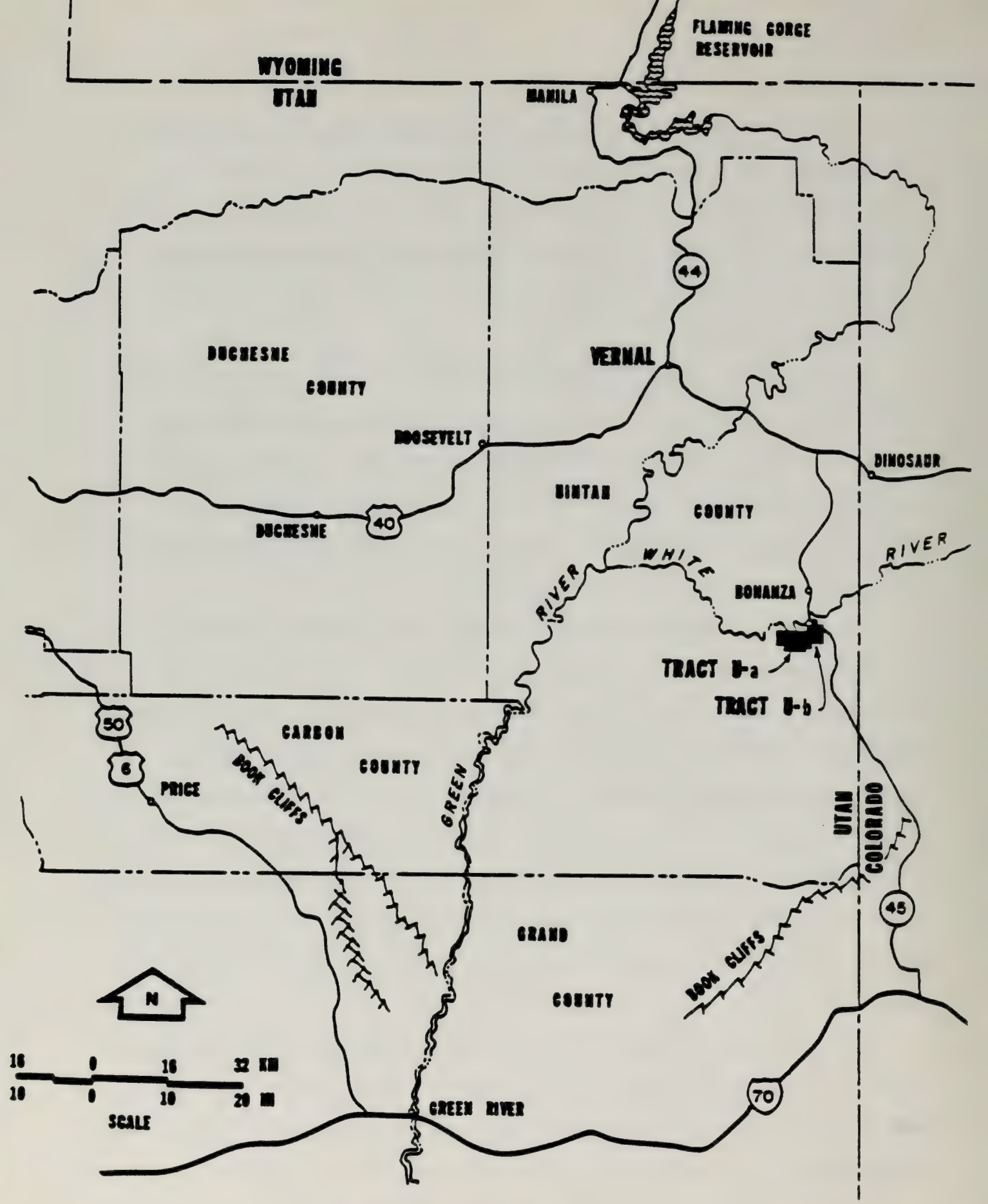
1.2 BACKGROUND

The White River Shale Project (WRSP) was established in 1974 to plan for and implement the joint development of Tracts Ua and Ub. Each tract encompasses 5120 acres of federal land. Figure 1.2-1 shows the location of the leased lands. The lease to Tract Ua is held equally by Phillips Petroleum Company and Sunoco Energy Development Co. The lease to Tract Ub is held by Sohio Shale Oil Company.

The White River Shale Oil Corporation (WRSOC), in its agency relationship to the lessees of Tracts Ua and Ub, has been retained to manage development of the WRSP. Thus, the WRSOC is responsible for implementation of environmental monitoring requirements mandated by the oil shale leases. Environmental monitoring programs for the WRSP are conducted by independent environmental consulting firms under contract to the WRSOC.

Four significant environmentally oriented tasks have been completed for the WRSP since work under the leases began in 1974. First, the "Detailed Development Plan," or DDP, required by lease provision was submitted to the Department of Interior - Oil Shale Office in June, 1976 and subsequently revised, updated, and resubmitted in September, 1981. This plan describes the schedule, activities, and expected results associated with planning, construction, operation, and abandonment of a commercial oil shale processing facility on Tracts Ua and Ub. The DDP was approved in March, 1982 following the lifting of a court-imposed injunction which had suspended tract development since May, 1977.

Second, the lease required two-year environmental monitoring and data collection program was completed for the WRSP in January, 1977. The results of this significant effort were published in October, 1977 as the "Final Environmental Baseline Report." Annual "Progress Reports," such as this



PROJECT LOCATION MAP
TRACTS U-a & U-b

FIGURE
1.2-1

document, have been prepared in the interim (1977-1981) to present data from the WRSP's on-going monitoring program which updates environmental conditions on the lease tracts. Monitoring continued during the interim period in order to confirm observations made during the Baseline period. evaluate environmental trends apparent only through multi-year study, track ambient ozone levels over an extended period and evaluate more refined biological resources monitoring techniques.

Third, to develop a technology for revegetating disturbed sites and reclaiming processed shale disposal areas, a study was conducted from November, 1974 through December, 1978. The final report, "Revegetation Studies for Disturbed Areas and Processed Shale Disposal Sites," was published in June, 1979. The WRSP reclamation research program has continued and the annual reports have provided updated information on the results of research studies supported by the WRSP.

Fourth, as tract development progressed into the construction stage (and subsequently into operation) it became apparent that the WRSOC must establish a monitoring philosophy based upon an acquired understanding of the tract ecosystem to guide the future WRSP monitoring program. Thus in June, 1982 the "Environmental Monitoring Manual" was published which establishes a detailed environmental monitoring program for the WRSP that will track the impacts of project development, evaluate the success of our planned mitigation measures, and provide feedback to design and operations to minimize and correct any identified adverse effects.

Construction is now in progress at the WRSP and monitoring is proceeding according to the plan established by the Environmental Monitoring Manual.

1.3 SUMMARY OF RESULTS

Monitoring of environmental conditions on and near to the tracts has been an on-going activity at the WRSP since 1974. The 1982 monitoring program involved six major disciplines, including air resources, vegetation resources, aquatic biology terrestrial fauna water resources, and reclamation research studies. The principal goals of the 1982 program were to finalize characterization of baseline conditions and to initiate investigation of tract development related impacts. The following summarizes the results of the 1982 WRSP monitoring program.

Precipitation in 1982 was well above average at the WRSP precipitation monitoring stations. Annual precipitation for the 1982 water year ranged from 13.80 inches to 15.73 inches at WRSP's ten precipitation gauges. The above normal precipitation was primarily the result of several large scale fall and summer storms. Net evaporation for the freeze-free period of May through September was similar to previously collected records and ranged from 24.76 to 27.09 inches.

Streamflow for the White River during 1982 was somewhat above normal at the two in-stream monitoring stations above and below the tracts. The daily discharge of the White River at USGS surface water station 6395 (Stateline) varied from 2720 cubic feet per second (cfs) in May, 1982 to 160 cfs in January, 1982. The 1982 annual runoff for station 6395 was 573,200 acre-feet which is well above the long-term average of 502,300 acre-feet for this station (based upon 56 years of record).

Annual suspended sediment and water quality records for the White River did not indicate any major differences between the upstream station (6395) and the downstream station (6700) during 1982. Nor was there a statistical difference between 1982 records and those of previous years.

Annual runoff and maximum instantaneous discharge for Evacuation Creek near the mouth (station 6430) during 1982 were the highest for eight years of record. This was due to numerous and wide-spread summer precipitation events occurring at higher elevations in the watershed (off-tract to the south). Water quality data were generally similar to previous years' records.

Drywash monitoring continued in the Plant Site Wash (station 6602), Southam Canyon (station 6610), and Asphalt Wash (station 6625). Southam Canyon discharges were higher than normal. Annual runoff for the Plant Site Wash was 7.9 acre-feet. Water quality records for Southam Canyon were similar to data from previous years. Certain water quality records for the Plant Site Wash (noteably suspended sediment, nutrients, iron and nickel) were higher than expected. This is attributed to construction activities in the Plant Site Wash drainage.

Static water level monitoring in Birds' Nest Wells was continued with notable differences detected from previous year records. Uncharacteristic water level fluctuations occurred at well P-1. This phenomena may have resulted from surface excavation blasting to support construction of a new access road. Also, several Birds' Nest Zone wells in the northern and western portion of the tracts (P-2 Lower, G-5, G-15, and G-21) continued to show steadily declining water levels. Two additional wells (G-10 and G-11) also began to show declines in 1982. These declining levels, which do not represent significant depletions from storage, were not associated with tract development activities.

The air resources monitoring program at the WRSP continued during 1982 with three sites measuring air quality parameters and five sites measuring macro-meterological parameters. The air program underwent several modifications during 1982 in response to the construction activities.

The role of monitoring background air quality shifted from site A6 to site A4 because of construction development near A6. Transfer of air quality measurements from A6 to A4 began in April and was completed in July. Air quality measurements at A6 were suspended in September and will not be reinstituted until Phase I operations. Meterological measurement continued at A6.

Site A10 was relocated and reactivated during 1982 to evaluate impacts of construction during drainage flows. This site monitors total suspended particulate and certain meterological parameters.

Overall air quality levels during 1982 did not change appreciably from previous years and were generally lower than baseline concentrations. NO/NO_x levels were occasionally higher at A6, probably due to blasting activities near the site. Ozone concentrations peaked at 135 $\mu g/m^3$ in the spring, compared with the national standard of 235 $\mu g/m^3$ and baseline values of 150 $\mu g/m^3$. Particulate concentrations (based upon annual geometric mean) were 14.5 $\mu g/m^3$ compared with the secondary standard of 60 $\mu g/m^3$. The peak 24-hour particulate concentration was 75.9 $\mu g/m^3$ compared with the secondary standard of 150 $\mu g/m^3$.

Sound level measurements also continued at five sites. In areas away from construction activity natural background levels ranged from 24dB(A) in isolated areas with no wind to 60dB(A) near the White River. The highest recorded measurement was 74dB(A) and was influenced by construction development.

Biological resource monitoring continued during 1982 with evaluation of vegetation resources, aquatic biology and terrestrial fauna and continuation of the WRSP sponsored reclamation research program. The biological program scope of work followed very closely the plan described in the Environmental Monitoring Manual.

The vegetation monitoring program included eight interrelated tasks to describe the health of tract vegetation and its relationship to biotic and abiotic factors. Annual plant biomass was relatively high in 1982. This parameter appears to correlate better with October-May precipitation than strictly spring (April-June) precipitation. Production and annual cover of annuals ranged from 68.1 gm/m^2 and 18.2% for riparian areas to 0.4 gm/m^2 and 0.2% for Juniper areas.

Sagebrush stem leader growth was low during 1982 despite good fall-winter precipitation. While this is within the 95% prediction interval established by the regression equation (determined based upon seven years of data), further evaluation of this finding is required.

In other vegetation studies, sagebrush leaders were analyzed for nine trace elements to define a natural background for these compounds which may be associated with emissions from the WRSP. Litterfall measurements were continued, with a six fold increase in the number of litter traps, to assess the vigor of seven dominant floral species and provide information on nutrient cycling and food resource recharge. A study was also begun using Cole Browse Survey methods to assess utilization of plants by animals. Also, color infra-red aerial photographs were taken to assess plant condition and stress. The 1:2400 scale was determined to be the most appropriate in measuring vegetation stress in sparsely vegetated areas.

Lichen monitoring also continued at 21 stands along three transects extending outward from the plant site. An elemental analysis was conducted on saxicolous lichen to establish a baseline for these parameters. Continued lichen monitoring will emphasize total cryptogamic cover number of species/ quadrat, and sulfur content of lichen tissue.

Soil microbiology and soil chemistry analysis were also conducted. While soil pH, organic carbon, and conductivity levels did not vary over the year or between sites, soil moisture showed a high in February and a low in June. Soil bacteria and respiration rates correlated well with soil moisture levels.

Aquatic biology monitoring during 1982 was a continuation of the program reestablished at the WRSP in 1981. During 1982 biological conditions in the White River were dominated by physical factors. Production was very low compared to 1981 due to high river levels, frequently high suspended sediment levels, and reduced light penetration occurring as a result of thunderstorm activity. The high river flows also contributed to temporal changes in nutrient levels.

An investigation of the role of metals in the White River was begun. Generally, metal levels in White River biota were found to be higher than the literature shows for other river systems in non-industrialized areas. The input from Evacuation creek and the proximity of oil shale and marlstone outcrops are probable causes for these naturally occurring high levels. The aquatic system is well adjusted to this condition.

Also, work continued on the P/R chambers and leafpack systems. These developing in-situ monitoring tools will allow rapid analysis of production, respiration and decomposition rates which are key to evaluating the health of the aquatic system.

Five major groups of terrestrial fauna were emphasized during 1982. These included soil invertebrates, foliage invertebrates, reptiles, birds, and mammals.

Soil invertebrate parameters differed significantly among the sampling sessions during 1982 in response to the changing climatic conditions. Foliage

invertebrates likewise varied with climatic conditions but also plant phenology and production. Amphibian and reptile populations showed declines from previous years due to generally wet conditions in the winter and fall and a relatively cool spring. The riparian area was the exception where increasing reptile population was noted.

Bird populations declined in all habitats except riparian in 1982. This is apparently due to low spring precipitation. The riparian bird population increased in response to higher food availability near the river as high flows increased habitat for insect production. In February ten bald eagles were surveyed wintering near Tracts Ua and Ub. A total of 58 raptor nests involving seven species were located in a 55 square mile area on or near the tracts. Eleven nests were active, including three golden eagle nests.

Mammal populations generally increased in most habitats, especially riparian. This appears to be related to abundant fall precipitation. Mule deer populations remain low with mean herd sizes ranging from two to six per siting.

Reclamation research continued during 1982 with both greenhouse and field studies in progress. The research completed to date has provided information pertinent to revegetation of both disturbed and processed shale areas. Plant species have been identified and methodologies listed which provide valuable direction in meeting the reclamation requirements of the Prototype leases.

Annual plant succession studies on processed shale at Anvil Points, Colorado began in 1981 and are yielding valuable information on means of rapid initial stabilization of the surface of processed shale and the reestablishment of organic matter. Root growth studies in processed shale, begun in 1979, continue to show spreading of healthy roots from soil trenches into processed shale. Soil and plant tissue studies analyze plant tolerance levels

to salt buildup. Plant establishment test plots on both disturbed areas and processed shale continue to show high survival rates for many species.

Recently initiated studies include establishment of a topsoil stockpile to investigate changes in microbiology that may occur with long-term storage and to evaluate methods of pile stabilization. Also, a study is continuing to assess various methods for enhancing wildlife habitat.

Greenhouse studies were initiated in 1982 to investigate the physical and chemical properties of circular grate processed shale and the response of seed germination and growth to those charactristics.

AIR RESOURCES

2.0 AIR RESOURCES

2.1 INTRODUCTION

The air quality on Tracts Ua and Ub has been monitored continuously by AeroVironment Inc. under contract to WRSP since baseline data collection began in 1974. As data on baseline pollutant levels were obtained and their general lack of spatial variation was demonstrated, the number of monitoring stations was reduced during the second year of the baseline period. The objectives of these baseline measurements were twofold:

- To characterize the air quality environment in the vicinity of the tracts in sufficient detail to provide a complete description of the baseline situation against which future air quality could be compared.
- To describe the meteorological environment in the vicinity of the tracts in sufficient detail to provide input data for modeling to simulate the dispersion of air pollutants that would be generated by future developments on the tracts.

The air resources baseline monitoring program was officially completed on 15 January 1977. The baseline years referred to in this report are 1975 and 1976. From January 1977 through 1981, monitoring of air quality has continued at one site and meteorological measurements have continued at four sites. This additional monitoring, known as the Air Resources Interim Monitoring Program, has provided continuity for the baseline program and helped satisfy a third objective:

- To determine the year-to-year variation in the baseline air quality and meteorology of the area, in order to see whether the baseline measurements adequately represented the ambient conditions.

Data collected from 1974 through 1981 were analyzed and summarized in other reports (White River Shale Project Reports, 1976 through 1982; Detailed Development Plan, 1981; and PSD Permit Application, 1981). The following describes the monitoring program in 1982 and discusses the data collected during the year.

2.2 SUMMARY

The beginning of construction for Phase I of the WRSP during 1982 resulted in some changes for the air quality monitoring program for Tracts Ua-Ub. The changes are consistent with the Environmental Monitoring Manual and reflect the dynamics of the monitoring program in keeping abreast with development. Construction activities do not affect meteorological values so only one modification was made to this program in 1982. In mid-June, recording of wind speed and wind direction began at Site A10, as scheduled in the monitoring program.

The role of monitoring background air quality shifted from Site A6 to A4, because Phase I construction had begun near the A6 site, possibly biasing the levels measured. Total suspended particulate (TSP) measurements started at A4 in mid-April, ozone (O_3) monitoring started in late May and sulfur dioxide (SO_2), carbon monoxide (CO) and nitrogen oxides (NO/NO_x) monitoring started in mid June. Although air quality data were collected at A6 through September, because of the possibility of interference from construction activities near A6, A4 data were used as soon as possible to represent background. Therefore, the following analyses, tables and figures discussing background air quality are based on data collected for part of the year at A6 and the remainder of the year at A4. The general breakdown is as follows:

TSP:	A6 -- January through mid-April
	A4 -- mid-April through December
O_3, SO_2, CO, NO/NO_x:	A6 -- January through June
	A4 -- July through December

To monitor the impact of construction during drainage flow, Site A10 started recording TSP levels in June of 1982. This site is also recording wind speed and direction, as mentioned previously. Site A10 was moved from its original baseline location, which will be submerged when the reservoir on the White River is complete, to above the reservoir's predicted high water level.

Overall, air quality levels measured during 1982 did not change appreciably from previous years. NO/NO_x levels were occasionally higher during the summer at Site A6, probably due to blasting activities. In general, all annual pollutant concentrations measured during 1982 averaged less than baseline concentrations.

2.3 PROGRAM DESCRIPTION

With the initiation of construction activities on Tracts Ua and Ub in 1982, ambient levels of particulates and gaseous pollutants are expected to change. Thus, the air resources monitoring program will take on new objectives. These are:

- To quantify the air quality impacts of various levels of oil shale development and operation on Tracts Ua and Ub;
- To demonstrate that impacts of the air contaminants emitted by the facilities are in compliance with the National Ambient Air Quality Standards (NAAQS) and the Prevention of Significant Deterioration (PSD) provisions of the Clean Air Act, as well as with Utah air quality standards;
- To identify areas where additional control of air contaminant emissions would be appropriate or necessary;
- To continue observing the long-term evolution of regional air quality;
- To continue monitoring the meteorological environment to provide additional data for future modeling efforts as well as to monitor meteorological events (such as frontal passages) that might affect the regional air quality.

A Development Monitoring Program has been designed to achieve these objectives and is presented in the Environmental Monitoring Manual (White River Shale Oil Corporation, 1982). Monitoring activities in 1982 followed those described in the Environmental Monitoring Manual and marked the

transition from the Interim Monitoring Program to the Development Monitoring Program.

Figure 2.3-1 shows meteorological stations that were operational at the beginning of 1982, and Figure 2.3-2 shows the stations that were operational at the end of 1982. The periods of operation of these stations are presented in Table 2.3-1. As pointed out in the Environmental Monitoring Manual, air quality monitoring at Site A6 was to be suspended during the construction phase of the project. Thus, when construction began in the summer of 1982, air quality monitoring was scheduled to be stopped in October. This plan, however, was thwarted by a thunderstorm in late September, which damaged most of the electric equipment at Site A6. No attempts were made to revive air quality monitoring at Site A6. Air quality monitoring at A6 will be resumed prior to Phase I operations.

2.3.1 Air Quality Monitoring Program

Table 2.3-2 lists the instruments used to monitor the air quality parameters during 1982. All instruments comply with EPA regulations. Table 2.3-2 also shows detection limits and data precisions and validity of all the instruments. All parameters, except total suspended particulates, are monitored continuously. Data are recorded on digital punched tapes every six minutes and on strip charts every two minutes. Total suspended particulates are measured over a 24-hour period every sixth day at A6 and measured daily at Sites A4 and A10.

The percentage of time each air quality parameter was monitored on Tracts Ua and Ub in 1982 is presented in Table 2.3-3. For TSP, the calculation was based on the designated TSP samplers and not the collocated samplers.

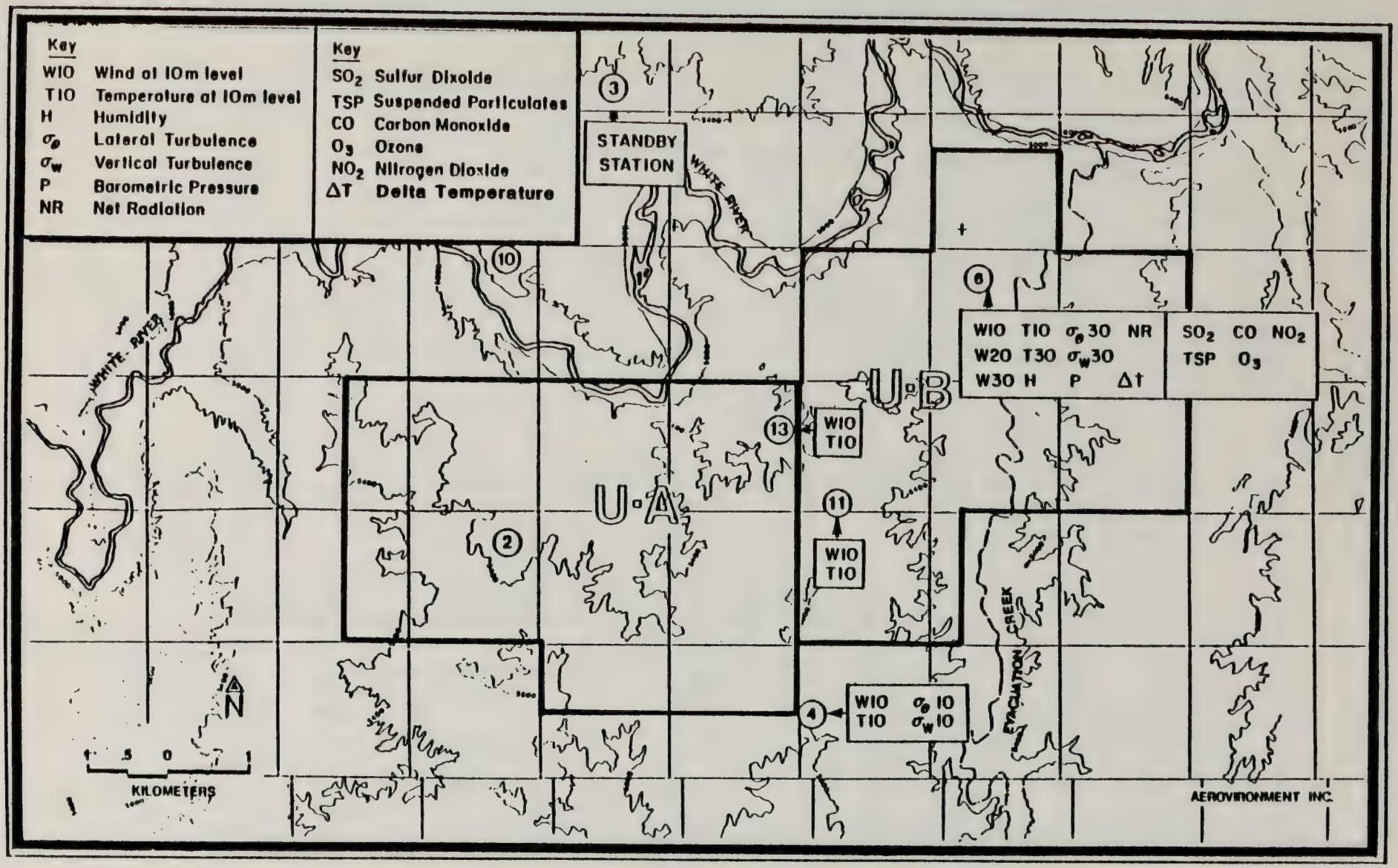


FIGURE 2.3-1. Locations of meteorological and air quality measurement stations on Tracts Ua and Ub at the beginning of 1982.

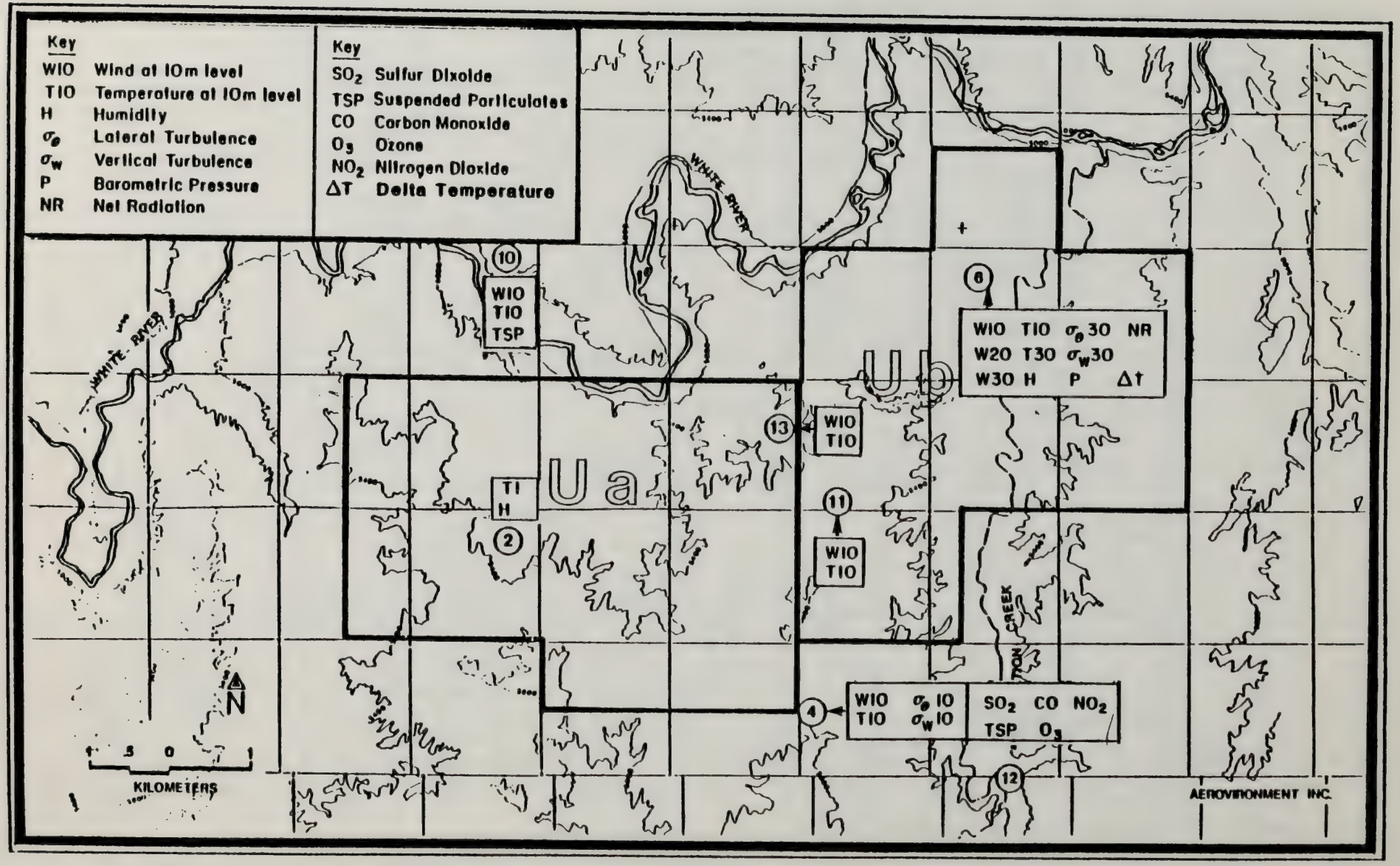


FIGURE 2.3-2. Locations of meteorological and air quality measurement stations on Tracts Ua and Ub by the end of 1982.

TABLE 2.3-1. Periods of measurements.

Site	Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
A2	T1	X	X	X	X	X	X	X	X	X	X		
	H	X	X	X	X	X	X	X	X	X	X		
A4	W10	X	X	X	X	X	X	X	X	X	X	X	X
	T10	X	X	X	X	X	X	X	X	X	X	X	X
	$\sigma_\theta 10$	X	X	X	X	X	X	X	X	X	X	X	X
	$\sigma_w 10$	X	X	X	X	X	X	X	X	X	X	X	X
	SO_2						X	X	X	X	X	X	X
	CO						X	X	X	X	X	X	X
	NO_2						X	X	X	X	X	X	X
	TSP				X	X	X	X	X	X	X	X	X
	O_3						X	X	X	X	X	X	X
A6	W10	X	X	X	X	X	X	X	X	X	X	X	X
	W20	X	X	X	X	X	X	X	X	X	X	X	X
	W30	X	X	X	X	X	X	X	X	X	X	X	X
	T10	X	X	X	X	X	X	X	X	X	X	X	X
	T30	X	X	X	X	X	X	X	X	X	X	X	X
	$\sigma_\theta 30$	X	X	X	X	X	X	X	X	X	X	X	X
	$\sigma_w 30$	X	X	X	X	X	X	X	X	X	X	X	X
	NR	X	X	X	X	X	X	X	X	X	X	X	X
	H	X	X	X	X	X	X	X	X	X	X	X	X
	P	X	X	X	X	X	X	X	X	X	X	X	X
	SO_2	X	X	X	X	X	X	X	X	X			
	CO	X	X	X	X	X	X	X	X	X			
	NO_2	X	X	X	X	X	X	X	X	X			
	TSP	X	X	X	X	X	X	X	X	X			
	O_3	X	X	X	X	X	X	X	X	X			
A10	W10						X	X	X	X	X	X	X
	T10						X	X	X	X	X	X	X
	TSP						X	X	X	X	X	X	X
A11	W10	X	X	X	X	X	X	X	X	X	X	X	X
	T10	X	X	X	X	X	X	X	X	X	X	X	X
A13	W10	X	X	X	X	X	X	X	X	X	X	X	X
	T10	X	X	X	X	X	X	X	X	X	X	X	X

TABLE 2.3-2. Air quality monitoring equipment by parameter and the instrument lower detection limit, data precision, and lower limit of data validity during 1982.

Parameter	Monitoring Instrument	Instrument Lower Dectection Limit	Data Precision	Lower Limit of Data Validity
O_3	Monitor Labs Model 8410E ozone analyzer, chemiluminescence	2 $\mu g/m^3$	6 $\mu g/m^3$	6 $\mu g/m^3$
CO	Monitor Labs Model 8310 infrared	0.1 mg/m^3	0.1 mg/m^3	0.1 mg/m^3
NO_x	Monitor Labs Model 8440E NO/NO_x analyzer, chemiluminescence	5 $\mu g/m^3$	6 $\mu g/m^3$	6 $\mu g/m^3$
NO		5 $\mu g/m^3$	6 $\mu g/m^3$	6 $\mu g/m^3$
$NO_2(NO_x-NO)$		5 $\mu g/m^3$	12 $\mu g/m^3$	12 $\mu g/m^3$
SO_2	Thermo Electron Corp. Model 43 pulsed fluorescent SO_2 analyzer	25 $\mu g/m^3$	8 $\mu g/m^3$	25 $\mu g/m^3$
TSP	Sierra Instruments Model GMWC-2000H, Hi-Vol with constant flow	0.5 $\mu g/m^3$	+ 6% of Toad or 1 $\mu g/m^3$	1 $\mu g/m^3$

TABLE 2.3-3. Percentage of time air quality parameters were monitored during 1 January - 31 December 1982.

Component	Number of Stations	Percentage of Time Monitored
SO_2	2	92
NO_x	2	99
O_3	2	99
CO	2	99
Suspended Particulates	3	97

2.3.2 Meteorological Monitoring Program

Table 2.3-4 lists the meteorological monitoring equipment used. Meteorological data are collected continuously and recorded on digital punch tapes every six minutes. Strip charts are also used at Sites A4, A6 and A10 for backup records. Table 2.3-5 lists the percentages of data recovered for each meteorological parameter monitored on the tracts.

2.3.3 Sound Level Measurement Program

Sound level measurements are made weekly at locations shown in Figure 2.3-3. The equipment used is a Gruel R. Kjaer type 2225 integrating sound level meter.

2.3.4 Quality Assurance/Quality Control Program

The quality assurance program, including standard operating procedures for quality control purposes, is described in depth in the report, "Quality Assurance Plan for Air Resources Monitoring, Oil Shale Lease Tracts Ua-Ub" (AV-QA-8047R2, AeroVironment Inc., 1982). In 1982, the internal audits described in the report were done on 26-29 January, 21-24 April, 14-16 July and 7-9 November. We also participated in the U.S. EPA National CO Performance Audit Program in March 1982.

TABLE 2.3-4. Meteorological monitoring equipment by parameter and the instrument lower detection limit, data precision, and lower limit of data validity during 1982.

Parameter	Monitoring Equipment	Instrument Lower Detection Limit	Data Precision	Lower Limit of Data Validity
Wind Speed	Meteorology Research Inc. Model 1022 anemometer (Sites 4, 6, 10)	1 m/s	0.2 m/s	1 m/s
	Meteorology Research Inc. Model 1071 anemometer (Sites 11, 13)	1 m/s	0.2 m/s	1 m/s
Wind Direction	Meteorology Research Inc. Model 1022 anemometer (Sites 4, 6, 10)	N/A	5%	N/A
	Meteorology Research Inc. Model 1071 anemometer (Sites 11, 13)	N/A	5°	N/A
Temperature	Meteorology Research Inc. Model 840 (Sites 4, 6, 10)	$-30^{o}C$	$0.5^{o}C$	$-30^{o}C$
	Meteorology Research Inc. Model 1071 thermistor (Sites 11, 13)	$-34^{o}C$	1°	$-34^{o}C$
Delta Temperature	Meteorology Research Inc. Model 840 thermistor	N/A	$0.2^{o}C$	1°
Sigma Theta	Meteorology Research Inc. Model 1022 with sigma processor	0.5^{o}	1°	N/A
Sigma W	R.M. Young Model 27100, with AV sigma processor	0.05 m/s	0.05 m/s	0.05 m/s
Barometric Pressure	Science Associates No. 370	600 mm Hg	0.5 mm Hg	600 mm Hg
Net Thermal Radiation	Fritschen net radiometer	-0.40 Ly/min	0.05 Ly/min	-0.40 Ly/min
Relative Humidity	WeatherMeasure Inc. H321-S	0%	5%	5%

TABLE 2.3-5. Percentage of data recovered for meteorological parameters during 1 January - 31 December 1982.

Component	Number of Stations	Percentage of Time Monitored
Wind (10m)	5	100
Wind (20m)	1	88
Wind (30m)	1	96
Temperature (10m)	5	100
Δ Temperature (30-10m)	1	67
Relative Humidity	2	96
Sigma Theta	2	99
Sigma w	2	93
Net Thermal Radiation	1	91
Barometric Pressure	1	95

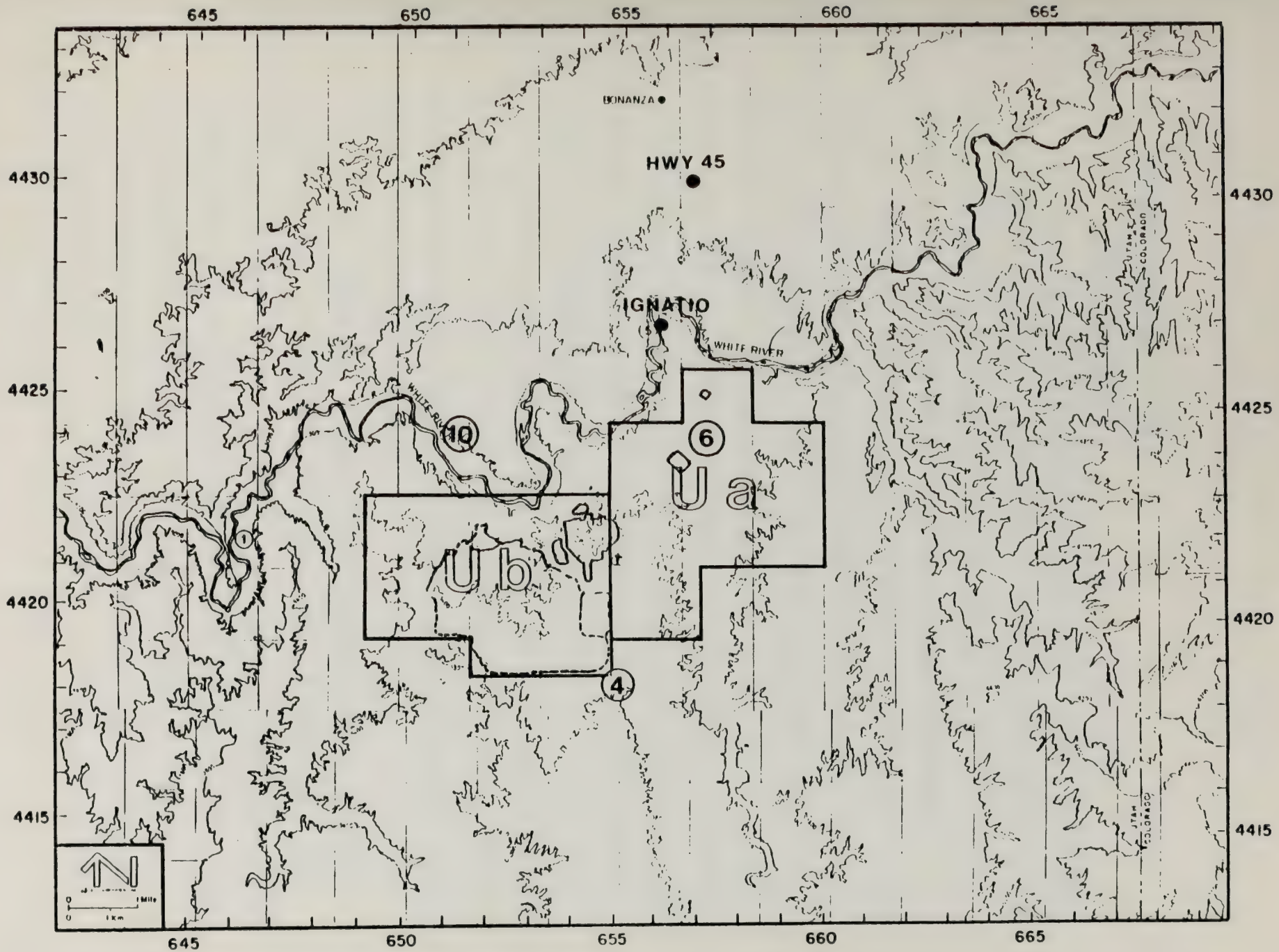


FIGURE 2.3-3. Sound level measuring sites.

2.4 PROGRAM RESULTS AND ANALYSIS

2.4.1 Gaseous Pollutants

Utah state air quality standards for gaseous pollutants are the same as the federal standards. For reference in the ensuing discussions, Table 2.4-1 gives the Utah State and National Ambient Air Quality Standards (NAAQS) for the various gaseous pollutants monitored on the tracts.

The air on the tracts was very clear of gaseous pollutants. The only pollutant present in measurable quantities was ozone, which has a natural non-zero background level. Occasional upward excursions of NO_x from the instrument threshold were also detected at Site A6 during 1982. These excursions are attributed to emissions from blasting in the vicinity of the station. Otherwise, almost all instruments measuring gaseous pollutants were recording at their threshold limit most of the time, the same situation as found during the baseline period.

The 1982 data were compared with the baseline (1975-1976) or long-term (1975-1980) data. Generally, the data exhibit no significant abnormalities with respect to earlier data. When appropriate, specific comments accompany the discussion of each parameter.

2.4.1.1 Ozone (O_3) Trends of the diurnal variation at Site A6 for January and July 1982 and baseline are shown in Figure 2.4-1. The daily minimum occurs in the early morning, while the daily maximum occurs in the afternoon. The biggest difference between the maximum and minimum ozone values occurs in July and the smallest difference in January.

Table 2.4-2 gives the monthly averages of ozone for 1982 compared to the baseline averages. Ozone values during the spring months, 1982,

TABLE 2.4-1. National and Utah air quality standards for gaseous pollutants.

Pollutant	Averaging Time	Primary Standards	Secondary Standards
Ozone (O_3)	1-hour	240 $\mu g/m^3$ (0.12 ppm)	Same as primary
Carbon Monoxide (CO)	8-hour	10 mg/m^3 (9 ppm)	Same as primary
	1-hour	40 mg/m^3 (35 ppm)	Same as primary
Sulfur Dioxide (SO_2)	annual average	80 $\mu g/m^3$ (0.03 ppm)	-
	24-hour	365 $\mu g/m^3$ (0.14 ppm)	-
	3-hour	-	1300 $\mu g/m^3$ (0.5 ppm)
Nitrogen Dioxide (NO_2)	annual average	100 $\mu g/m^3$ (0.05 ppm)	Same as primary

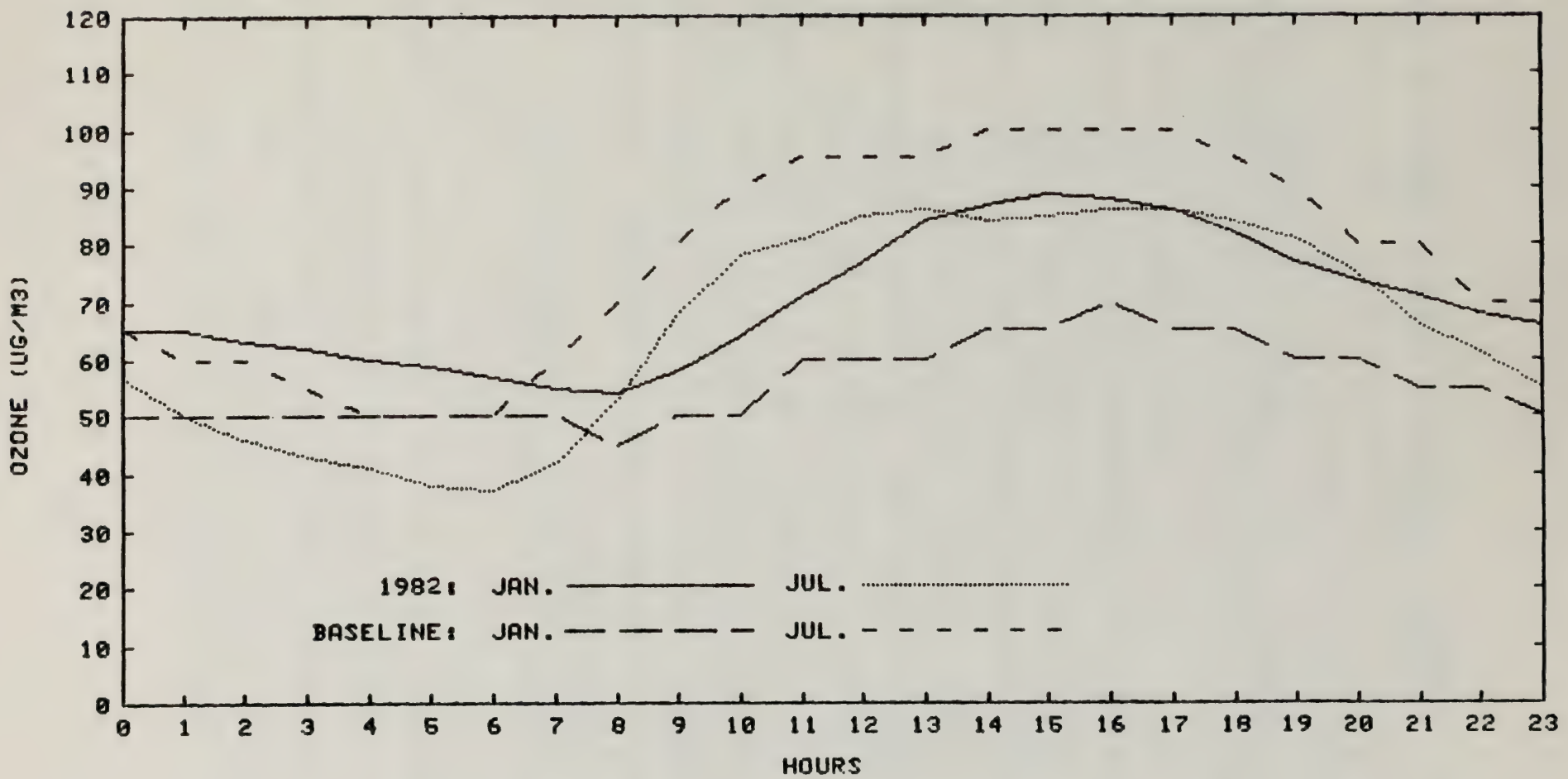


FIGURE 2.4-1. Diurnal variation of mean ozone concentrations at site A6 during January and July 1982 and January and July of the baseline period.

TABLE 2.4-2. Monthly average of 1982 O_3 ($\mu g/m^3$) compared to baseline values.

Month	Baseline	1982**
Jan	60*	70
Feb	70	60
Mar	70	63
Apr	80	62
May	75	70
Jun	70	74
Jul	80	72
Aug	70	76
Sep	65	47
Oct	55	84
Nov	45	64
Dec	50	64
Annual	67	67

*January 1976 only

**January-June is Site A6, July-December is Site A4

were slightly lower than baseline, while ozone was slightly higher during the fall and winter. During the spring months, there were several frontal passages but most of these were dry and weak and none of them brought high ozone. The majority of the time the area was under the influence of warm high pressure cells. For the rest of the year, the monthly averages were comparable to those of past years.

The seasonal highest hourly concentration, second highest hourly concentration, and seasonal averages for O_3 are given in Table 2.4-3. The highest and second highest values for 1982 were 135 $\mu g/m^3$ and 133 $\mu g/m^3$. These values were recorded during May and September, respectively. The 1982 seasonal values were lower than those observed during the baseline period. The nominal detection limit for the ozone analyzer is 2 $\mu g/m^3$ and the instrument's validity limit is ± 6 $\mu g/m^3$.

Figure 2.4-2 shows the monthly maximum hourly values and means, as well as the mean daily maximum hourly averages for 1982 compared to the baseline period. The highest maximums and means were in the late spring and late summer in 1982. The lowest averages occurred during late fall and early winter. The monthly maximum values for January, October and November were higher than baseline values. The mean daily maximum hourly averages for January through April had lower values than baseline.

Figure 2.4-3 shows the trend of monthly averaged ozone from February 1975 through December 1982. The highest monthly average of 96 $\mu g/m^3$ occurred in February 1979. That month was very cold and stormy with an unusual amount of upper-level ozone intrusions accompanying frontal passages.

TABLE 2.4-3. Comparison of the seasonal highest and 1-hour O_3 readings (in $\mu g/m^3$), as well as the seasonal averages at Sites A4 and A6 for the baseline period (1975-1976) and 1982.

Season	Peak Concentration		Second Highest Concentration		Seasonal Average	
	Baseline	1982	Baseline	1982	Baseline	1982
Winter	150	129	150	122	70	65
Spring	150	135	140	123	75	67
Summer	140	123	140	119	75	74
Fall	140	133	120	118	55	65

Note: Data based on Site A6 -- January through June 1982
Data based on Site A4 -- July through December 1982

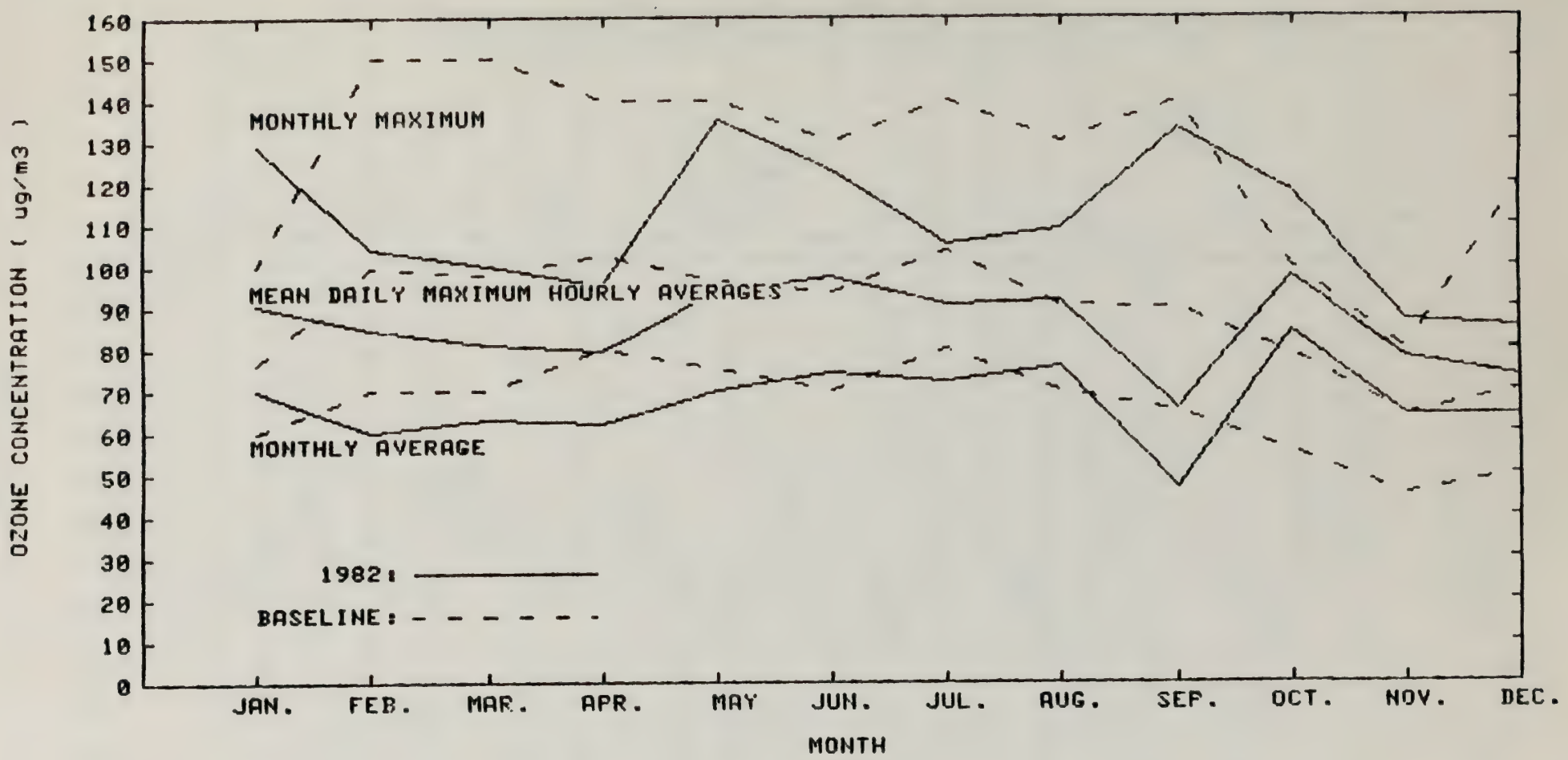


FIGURE 2.4-2. Monthly maximum hourly values, mean daily maximum hourly averages, and mean monthly values of O_3 at site A6 from January through June 1982 and site A4 from July through December 1982.

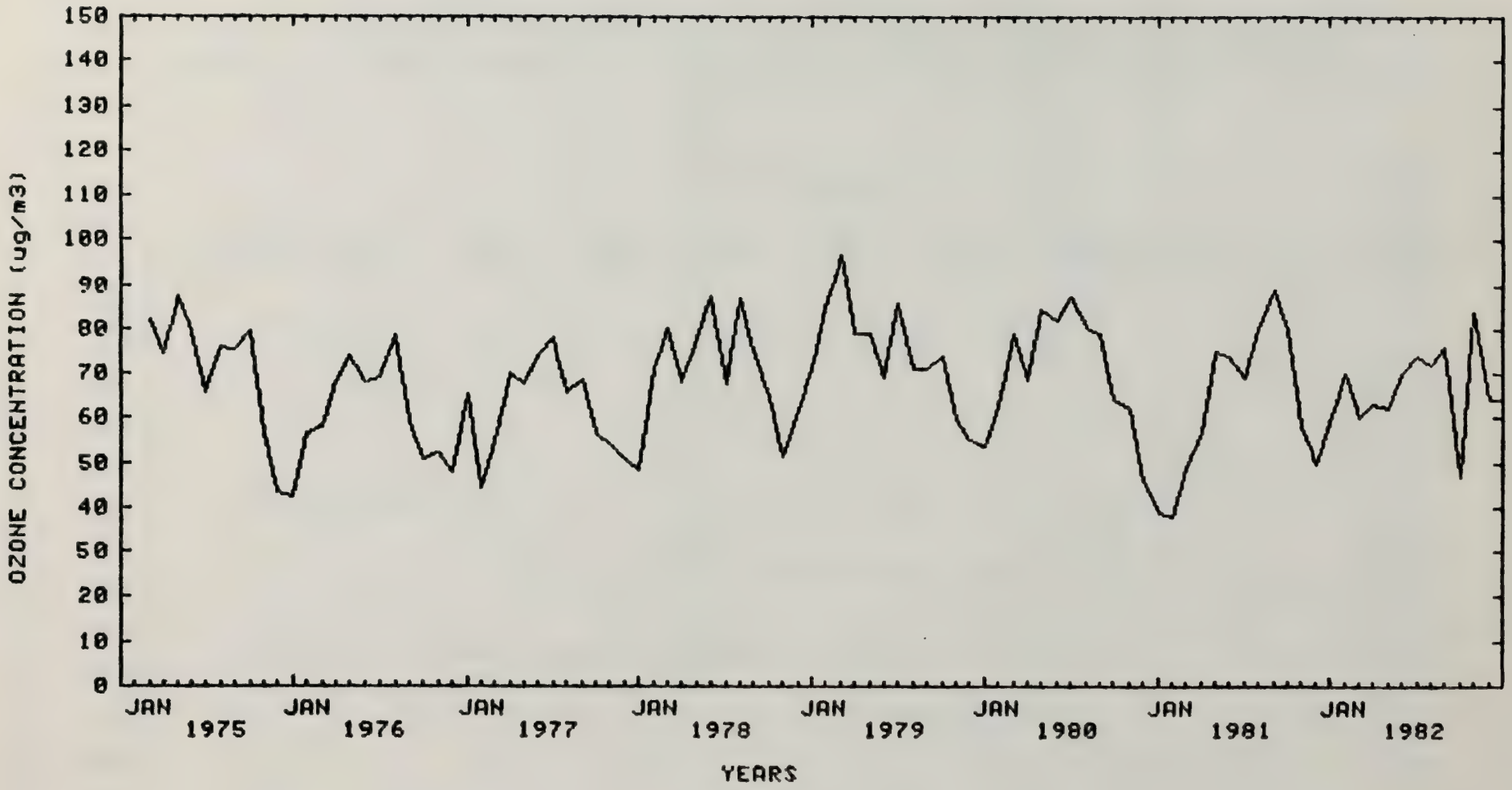


FIGURE 2.4-3. Trend of monthly average ozone at site A6 from February 1975 through June 1982 at site A6, July through December at site A4.

Ozone levels are generally lowest in October and November with peak values during the late spring, early summer months.

Figure 2.4-4 shows the trend in the annual averages of ozone at Site A6 since 1975.

Figures 2.4-5 and 2.4-6 show annual ozone pollution roses at Site A6 and Site A4 for 1982. The majority of low O_3 concentrations ($\leq 50\ \mu g/m^3$) occur with the wind blowing from the east-southeast at Site A6 -- the nighttime drainage flow. The highest values (100 to 150 $\mu g/m^3$) occur with the wind from a variety of directions at both Site A6 and A4, tending to rule out local precursors and implicate influxes of ozone from natural origins.

According to Chan and Smith (1981), the ozone concentrations at Site A6 depend a great deal on the ozone content of the troposphere. Year-to-year variability correlates with the passage of fronts over the site. Unusually high ozone concentrations ($>100\ \mu g/m^3$) can be attributed to ozone intrusions accompanying frontal passages, strong turbulent atmospheric mixing that brings ozone from aloft to the surface, or long-range transport from urban areas.

Ozone data collected simultaneously at Sites A6 and A4 were analyzed statistically for similarity to determine the degree of continuity in the background air quality data measured for Tracts Ua-Ub. The question is whether, on the basis of a 5% level of significance, there are significant differences between the means of ozone collected at Sites A4 and A6 for the period 16 June 1982 to 27 September 1982.

FIGURE 2.4-4 . Trend of annual average O_3 on the tracts.

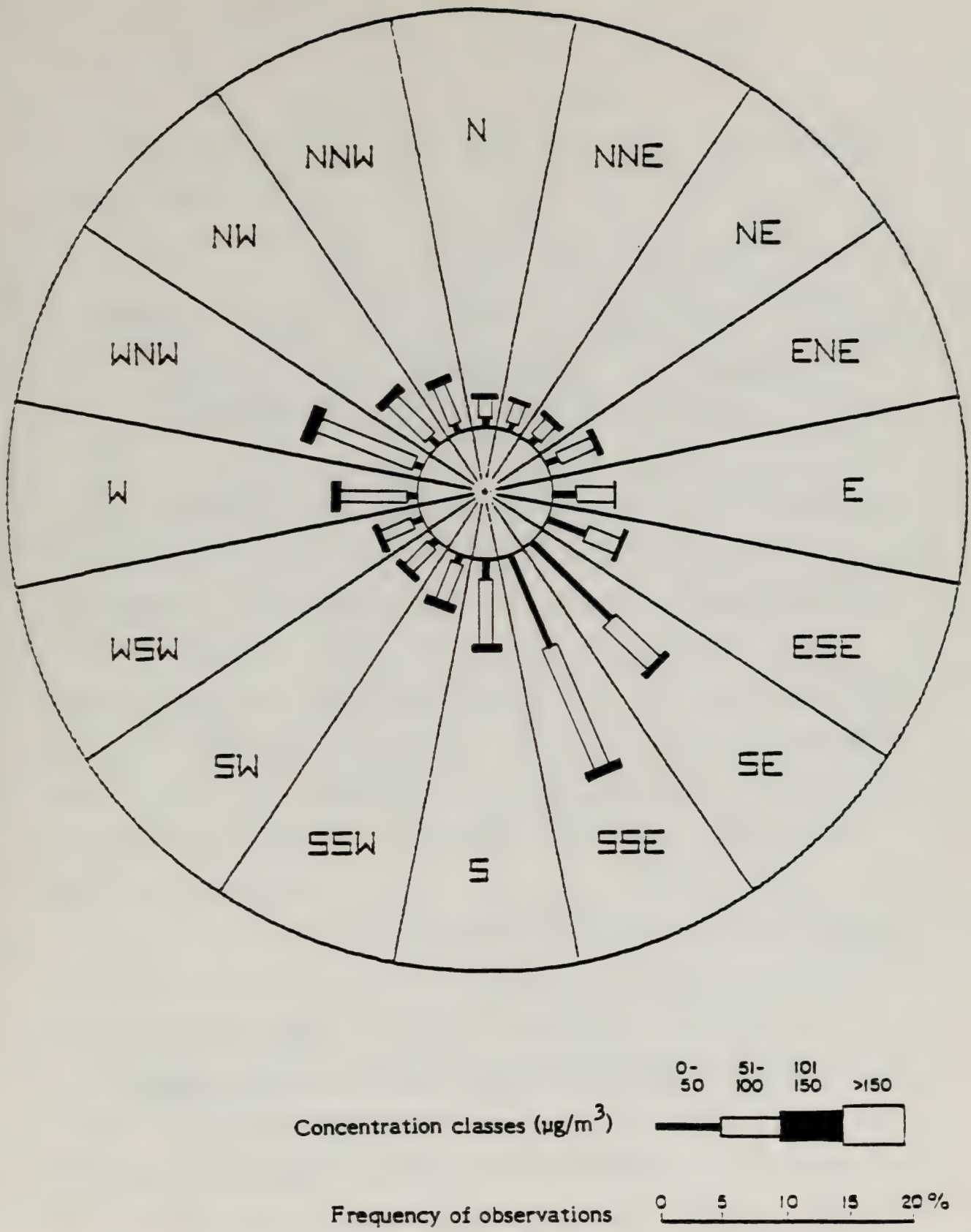


FIGURE 2.4-5. Annual ozone pollution rose at Site A6.

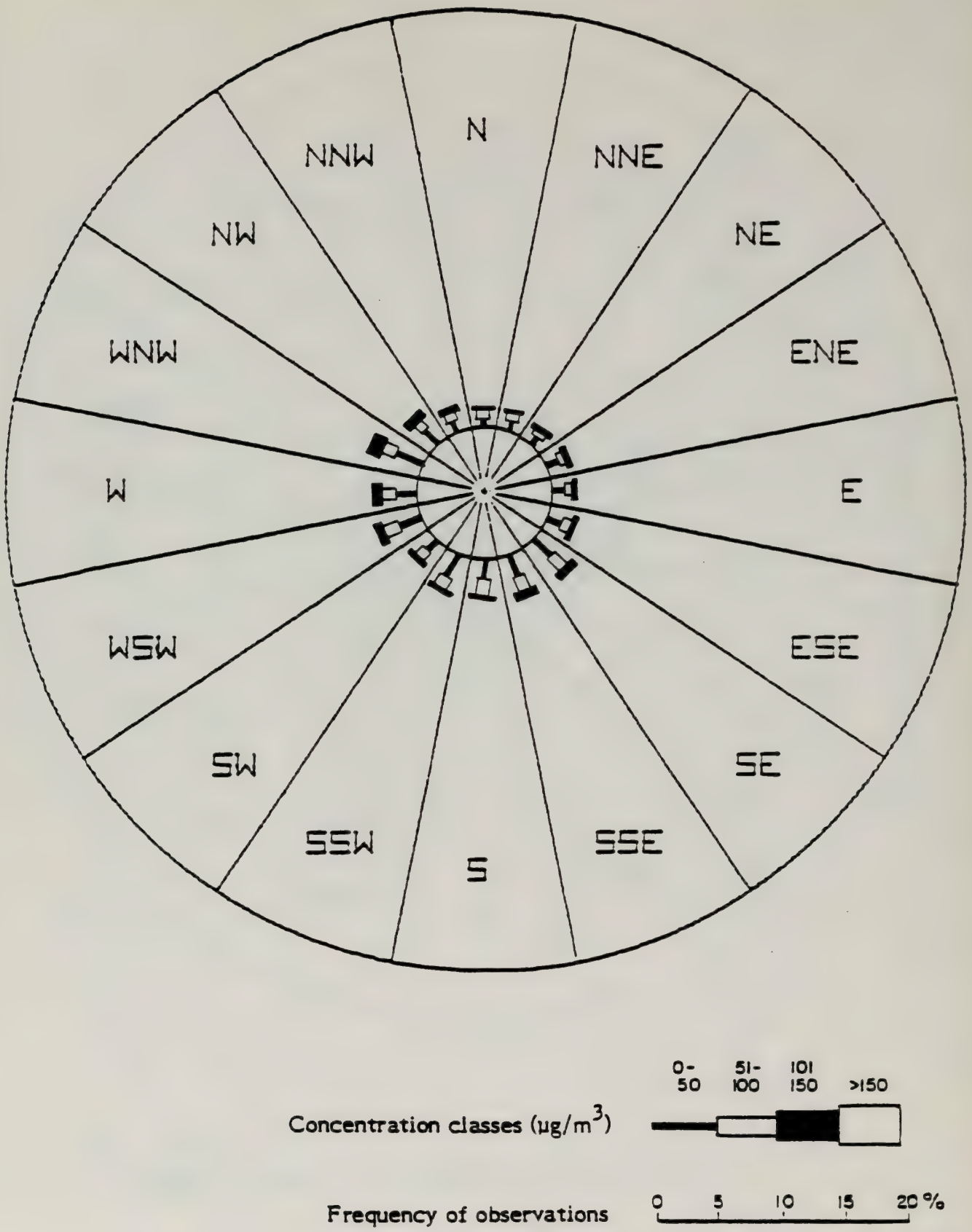


FIGURE 2.4-6. Annual ozone pollution rose at Site A4.

The following illustrates the mean, variance and standard deviation in ppm for both sites:

	Site A4	Site A6
Mean:	0.0332687	0.0324353
Variance:	0.000159940	0.000202405
Standard Deviation:	0.0126467	0.0142269

A two-tailed t-test was performed to determine if the mean ozone at A4 differed from A6, leading to $t_{N-2} = 1.7757234$. Therefore, since the critical t values are 1.96 and -1.96, with 95% confidence we cannot reject our hypothesis that the mean ozone values at A4 and A6 are the same. The best fit line by least squares has a slope equal to 0.864621 and an intercept equal to 0.00367044. The linear correlation coefficient equals 0.768588 with an "F" distribution of 2371.45 and a "standard error of estimate" of 0.00910436. Figure 2.4-7 is a scatter diagram of the ozone data at A4 and A6.

Since the analysis shows that with 95% confidence the null hypothesis cannot be rejected, the pollutant concentrations measured at Sites A4 and A6 do not differ significantly for background air quality.

2.4.1.2 Carbon Monoxide (CO) Table 2.4-4 gives the highest, second highest, and average one-hour and eight-hour CO concentrations at Sites A6 and A4 for each season. During 1982, the maximum one-hour concentration was 1.7 mg/m^3 and the maximum eight-hour reading was 1.2 mg/m^3. These are lower than the 3.0 mg/m^3 and 1.8 mg/m^3 recorded during the baseline period. Most of the values are near zero and overall CO levels have not

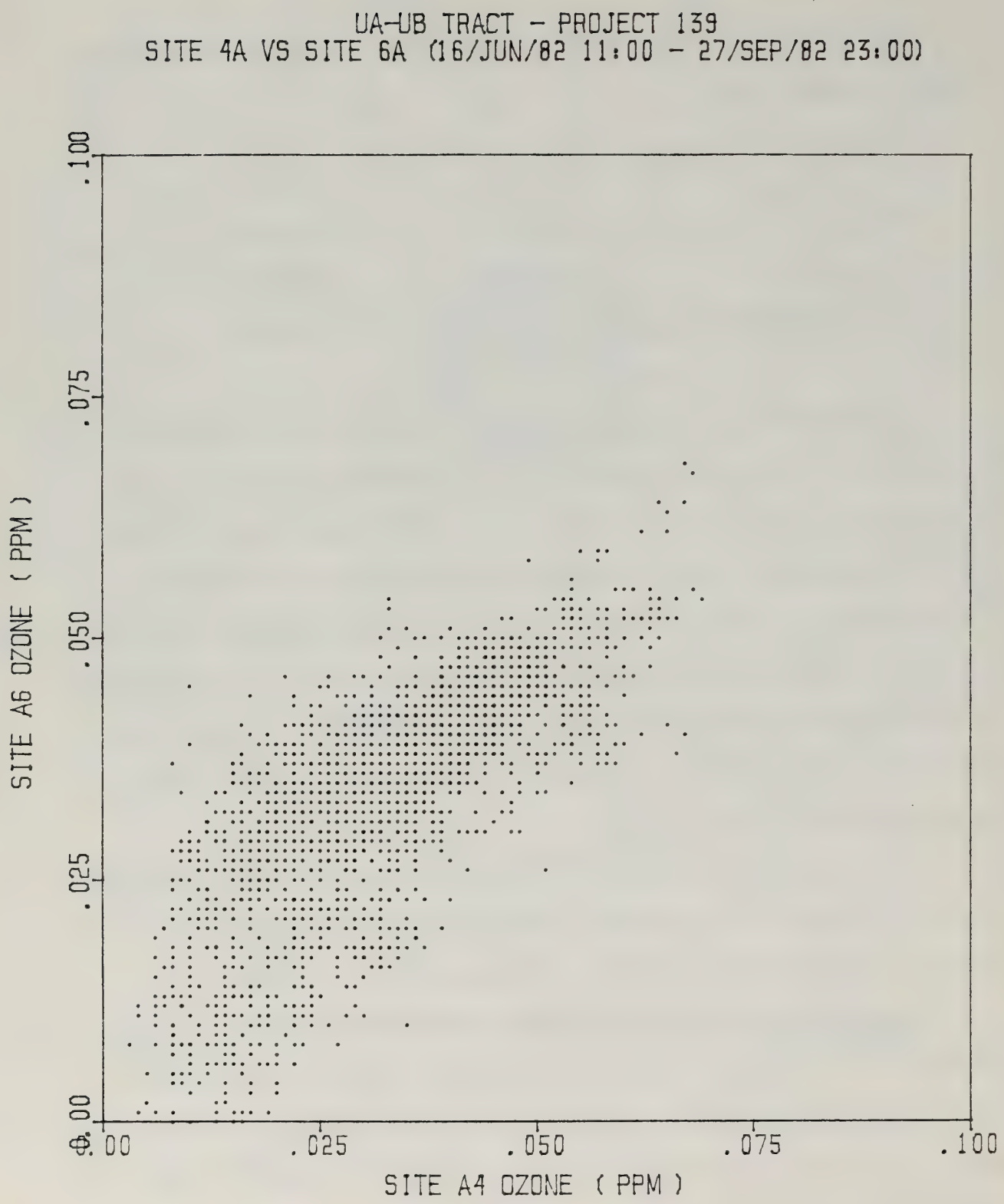


FIGURE 2.4-7. Plot of linear correlation.

TABLE 2.4-4. Comparisons of the seasonal highest and second highest 1-hour and 8-hour moving mean CO readings (in mg/m^3), as well as the seasonal averages at Sites A6 and A4 for the baseline period (1975-1976) and 1982.

Season	Averaging Time	Peak Concentration		Second Highest Concentration		Seasonal Average	
		Baseline	1982	Baseline	1982	Baseline	1982
Winter	1-hour	3.0	1.1	2.2	1.0	0.2	0.3
	8-hour	1.3	1.0	1.2	0.9		
Spring	1-hour	0.8	1.3	0.7	1.2	0.1	0.3
	8-hour	0.7	1.2	0.5	1.1		
Summer	1-hour	3.0	1.7	2.7	1.3	0.1	0.2
	8-hour	1.8	0.7	1.7	0.6		
Fall	1-hour	1.2	1.3	1.2	1.0	0.2	0.2
	8-hour	0.7	1.2	0.6	1.1		

Note: Data from Site A6 -- January through June 1982
Data from Site A4 -- July through December 1982

changed appreciably. All values are well-below the national standards of 40 mg/m^3 (one-hour) and 10 mg/m^3 (eight-hour).

The normal background level is 0.5 mg/m^3 and practically all the readings fall around or below this value. No diurnal or seasonal variations are observed in the CO levels. Readings are generally near the detection limit of the instrument, 0.1 mg/m^3.

2.4.1.3 Nitrogen Dioxide (NO_2) Of the nitrogen oxides, only NO_2 has a National Ambient Air Quality Standard (annual average of 100 $\mu g/m^3$). Table 2.4-5 shows the seasonal highest, second highest, and seasonal averages for both the baseline period and 1982. The California standard (for reference) is a one-hour average of 470 $\mu g/m^3$. This table also shows the annual averages. The highest and second highest one-hour values during 1982 were 61 and 47 $\mu g/m^3$, recorded during the summer season. Activity on the tracts during the first part of the Baseline Program could have produced the high values of 100 $\mu g/m^3$, and increased activity in 1982 probably produced the high readings during this period.

The precision of the instrument is around 12 $\mu g/m^3$ and readings are generally below this value and near the lower detection limit of this instrument (5 $\mu g/m^3$).

2.4.1.4 Sulfur Dioxide, SO_2 Table 2.4-6 compares the 1982 and baseline period's highest, second highest, and seasonal averages for both the three-hour and 24-hour readings of SO_2. No seasonal or diurnal trend is evident. Values are higher than in the past, although most values are near or below the detection limit of the instrument, 25 $\mu g/m^3$. The highest three-hour SO_2 reading of 37 $\mu g/m^3$ was recorded during the summer of 1982. The standard

TABLE 2.4-5. Comparisons of the seasonal highest and second highest one-hour NO_2 concentrations ($\mu g/m^3$) as well as the seasonal averages at Sites A4 and A6 for 1982 and Site A6 for the baseline period.

Season	Peak Concentration		Second Highest Concentration		Seasonal Average	
	Baseline	1982	Baseline	1982	Baseline	1982
Winter	30	31	30	27	2	4
Spring	20	30	20	26	2	6
Summer	100	61	90	47	12	2
Fall	100	26	80	20	5	1
Annual	100	31	90	36	5	4

Note: Site A6 data -- January through June 1982
Site A4 data -- July through December 1982

TABLE 2.4-6. Comparisons of the seasonal highest and second highest 3-hourly and 24-hourly-averaged SO_2 concentrations ($\mu g/m^3$), as well as the seasonal averages at Sites A6 and A4 during the baseline period (1975-1976) and 1982.

Season	Averaging Time	Peak Concentration		Second Highest Concentration		Seasonal Average	
		Baseline	1982	Baseline	1982	Baseline	1982
Winter	3-hour	10	20	8	19	1	6
	24-hour	5	13	5	12		
Spring	3-hour	10	24	10	23	1	11
	24-hour	5	20	5	19		
Summer	3-hour	15	39	12	33	3	6
	24-hour	10	23	10	22		
Fall	3-hour	7	6	7	5	1	2
	24-hour	5	5	5	4		

Note: Data from Site A6 -- January through June 1982
Data from Site A4 -- July through December 1982

for a three-hour averaging time is 1,300 $\mu g/m^3$. The highest 24-hour SO_2 reading was 23 $\mu g/m^3$, recorded during the summer. Again, this reading is well below the 24-hour standard of 365 $\mu g/m^3$. The annual average on the tracts has always been 10 $\mu g/m^3$, compared to the annual standard of 80 $\mu g/m^3$.

2.4.1.5 Total Suspended Particulate (TSP) Particulate concentrations are monitored by high-volume samplers which sample over a period of 24 hours once every six days at Site A6 and every day at Sites A4 and A10. The size of the particulate matter collected by the samplers ranges from below 1 μm to 100 μm. Two TSP samplers were operated at Site A6 until mid October, one called the designator and the other called the collocator. Two TSP samplers were installed at Site A4 in November.

The collocator was established to determine the precision of the TSP data. The accuracy of the data was determined through periodic audits. Standard procedures for calculating the precision and accuracy are detailed in the PSD guidelines Sections 6.3.2.1 and 6.3.2.2 (U.S. EPA, 1978). They also appear in 44 Federal Register 27477 (May 1979).

Table 2.4-7 shows the computed precision and accuracy of the TSP samples during days when both samplers were operating at Sites A6 and A4. This table includes only those days when both samplers were operating simultaneously for 24 hours. The wide range of the 95% confidence limits during the January-March quarter is attributed to the low concentrations recorded. For example, a difference of 1 $\mu g/m^3$ at values less than 20 $\mu g/m^3$ is significant, whereas at higher values, the percent difference would not be as significant. Some incomplete samples from the collocator during

TABLE 2.4-7. Precision and accuracy of the TSP samplers at Sites A6 and A4 during 1982.

Site	Reporting Period	Precision		Confidence Limit		Accuracy	
		No. of Collected Samples	No. of Official Samples 20 g/m^3	Lower 95%	Upper 95%	Audit Date	Percent Difference (Di)*
A6	January-March	13	10	-23.880	31.287	11/20/81	0.00
A6	April-June	13	0	-7.267	16.133	4/21/82	-0.01
A6	July-September	13	3	-11.01	31.471	7/15/82	-0.01
A4	October-December	8	7	-11.86	19.284	11/9/82	-0.01

$$*Di = \frac{Yi-Xi}{Xi} \quad 100$$

Xi -- known flow rate (m^3/min)

Yi -- audit flow rate (m^3/min)

the fall months were not included in the precision computations. Four internal audits for accuracy (November 1981, April, July, and November 1982) were conducted. Audit results of the designator sampler are also shown in Table 2.4-7.

Tables 2.4-8 and 2.4-9 gives the geometric mean, standard geometric deviation, maximum and minimum of the total suspended particulate concentrations in $\mu g/m^3$ at Sites A6, A4 and A10. The baseline period and 1982 values are shown by season for Site A6.

The geometric mean given can be considered to correspond to the concentration expected at a 50% frequency because particulate concentrations are generally lognormally distributed. The geometric mean particulate concentration during 1982 ranged from 8.5 $\mu g/m^3$ during the winter months to 19.1 $\mu g/m^3$ during the summer. The maximum 24-hour value for 1982 at Site A6 and A4 was 75.9 $\mu g/m^3$ recorded on 30 April 1982. The maximum value for Site A10 was 60.1 $\mu g/m^3$ recorded on 21 July 1982.

None of the recorded values exceeded national or state standards, which are given in Table 2.4-10. The most stringent short-term standard is the National Secondary Standard, which sets the upper limit at 150 $\mu g/m^3$, averaged over 24 hours; this is not to be exceeded more than once a year.

2.4.2 Background Averages

Table 2.4-11 gives the annual averages for the pollutants monitored on the tracts from 1975 through 1982. Generally, the values were slightly higher during 1982 for O_3, NO_2, and SO_2. The values recorded during the interim period are more representative of true background conditions since during this time activities on the tracts were at a minimum.

TABLE 2.4-8. Geometric means, standard geometric deviations, and maximum and minimum particulate concentrations ($\mu g/m^3$) for baseline period (1975, 1976) and 1982 at Sites A6 and A4.

	Season	Baseline	1982**
Geometric Mean	Winter	14.2*	8.5
	Spring	17.2	18.9
	Summer	37.0	19.1
	Fall	27.2	11.9
Standard Geometric Deviation	Winter	2.6*	1.8
	Spring	1.9	1.6
	Summer	1.4	1.5
	Fall	2.0	2.0
Maximum	Winter	51.9*	22.7
	Spring	42.0	75.9
	Summer	74.7	58.1
	Fall	101.2	43.3
Minimum	Winter	3.5*	1.4
	Spring	4.9	9.1
	Summer	18.7	6.4
	Fall	4.9	2.5
Geometric Mean	Annual	24.0	14.5
Standard Geometric Deviation	Annual	2.5	1.9

*1976 only, insufficient data for 1975.
**Site A6 -- January to mid-April 1982
Site A4 -- Mid-April through December 1982

TABLE 2.4-9. Geometric means, standard geometric deviations, and maximum and minimum particulate concentrations ($\mu g/m^3$) for 1982 at site A10.

	Season	1982
Geometric mean	Winter*	7.7
	Spring	--
	Summer	21.0
	Fall	11.5
Standard Geometric Deviation	Winter*	1.6
	Spring	--
	Summer	1.6
	Fall	2.0
Maximum	Winter*	20.1
	Spring	--
	Summer	60.1
	Fall	48.8
Minimum	Winter*	2.8
	Spring	--
	Summer	7.8
	Fall	2.6
Geometric mean	Annual	13.9
Standard Geometric Deviation	Annual	2.0

*Winter season includes data from the month of December only.

TABLE 2.4-10. National and Utah state ambient air quality standards for particulate matter ($\mu g/m^3$).

Pollutant	Averaging Time	Standards	
		Primary	Secondary
Suspended Particulate Matter	Annual Geometric Mean	75	60
	24-hour	260	150

TABLE 2.4-11. The annual averages ($\mu g/m^3$) for the gaseous pollutants and annual geometric mean for TSP during the entire period of monitoring.

Pollutant	Annual Averages							
	Baseline		Interim					
	1975	1976	1977	1978	1979	1980	1981	1982
O_3	70	63	61	72	73	69	65	67
CO (mg/m^3)	.2	.1	.2	.1	.1	.4	.3	.2
NO_2	5	5	0	1	1	2	1	4
SO_2	3	0	1	3	0	1	7	6
TSP	24.5	23.5	22.2	15.0	12.5	19.6	19.1	14.4

The changes in the annual geometric means for TSP during the past six years seem to be related to the changes in annual average wind speeds on the tracts at Site A6. The annual average wind speeds from 1975 through 1982 were 4.0, 4.2, 3.1, 2.8, 2.9, 3.1, 2.9, and 2.5 m/s, respectively.

2.4.3 Climatic Regimes

Before discussing the details of the transport and dispersion characteristics of the atmosphere over the Ua-Ub tracts, it would be appropriate to summarize the major weather systems that affect the large-scale movement of air masses over the area.

The horizontal transport of an air mass is a consequence of large-scale differences in air pressure. The factor determining Utah's weather during the winter months is the location and strength of the Intermountain Region High Pressure Cell. Figure 2.4-8a shows the normal January sea level pressure and temperature. Storm tracks during mid-winter tend to pass north through Montana and through southern Utah. After February, storm tracks are more prevalent over northern Utah as the strength of the Basin High wanes. Precipitation is highest during the spring months.

During the summer months (Figure 2.4-8b), the pressure is lower and sporadic moisture from the Gulf of Mexico brings periods of scattered thundershowers. Beginning September, the storm fronts from the north increase in probability but are interspersed with many periods of clear weather when high pressure builds up in the Intermountain Basin.

2.4.3.1 Synoptic Summary - 1982 The pressures were lower than normal over the Intermountain Basin during January, as highly variable weather patterns dominated the tracts. Pressure patterns into May, however, were

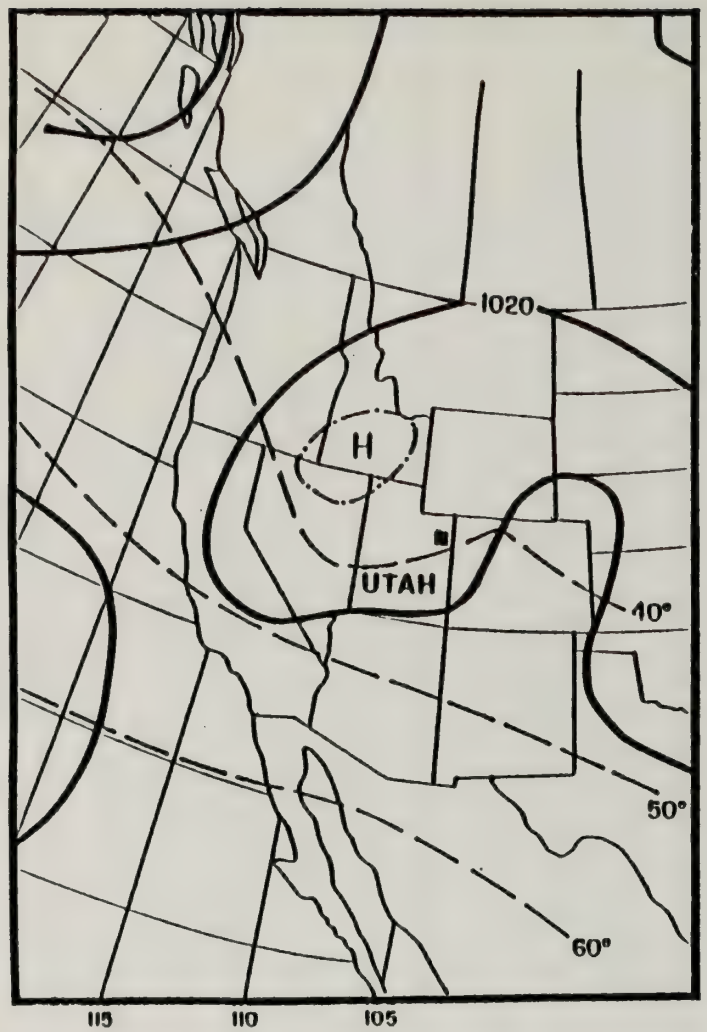


FIGURE 2.4-8a. Normal January sea level pressure in mb (solid lines) and temperature in °F (dashed lines).

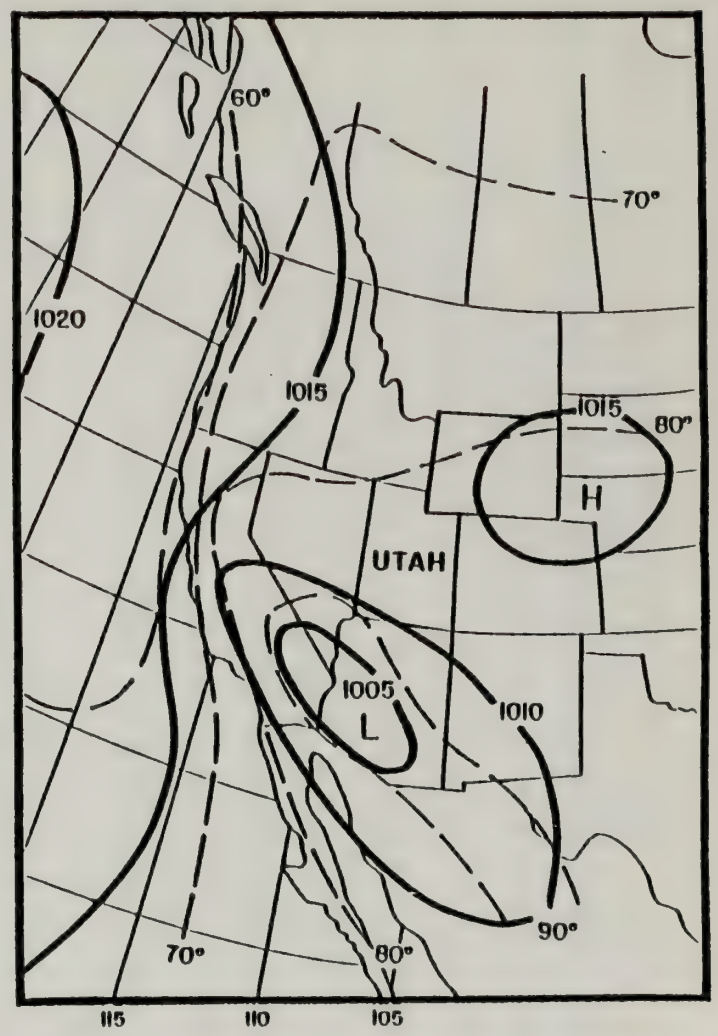


FIGURE 2.4-8b. Normal July sea level pressure in mb (solid lines) and temperature in °F (dashed lines).

Source: National Weather Bureau, 1952.

normal. Several periods of thunder storm activity occurred from May into September, especially during September when remnants of tropical storm Olivia brought 500% total rainfall for the month.

Increase in storm activity during October alternating with strong high pressure systems gave a hint of the storminess which came in November and December 1982.

2.4.4 Meteorological Data

Meteorological data for 1982 is summarized below and compared quantitatively with the Baseline (1975-1976) Program data to identify any significant changes.

2.4.4.1 Surface Flow As usual, the rugged terrain features in the area complicated the airflow pattern. Table 2.4-12 shows the prevailing direction and speed by month for the four wind sites. Spatial variation in wind speed on the tracts was also observed through the baseline and interim periods. Generally, nighttime drainage flow was prevalent throughout the year. Figure 2.4-9 shows the typical airflow streamlines for the early morning drainage pattern. The solid arrows on this figure are wind vectors at the monitoring sites, and the longer lines are estimated flow streamlines. The large open arrow depicts the mesoscale flow direction in the greater White River drainage basin. The drainage pattern did not deviate significantly throughout the year. This figure was prepared from averaged wind observations in 1982 at the four wind sites, plus knowledge of the wind flow pattern as presented in reports prepared for the baseline and interim periods. The drainage flow is always from higher to lower terrain, as noted during the baseline period.

TABLE 2.4-12. The monthly and annual prevailing wind direction/speeds (in m/s) at sites A4, A6, A10, A11 and A13 during 1982.

Month	Site				
	A4	A6	A10	A11	A13
Jan	W/2.7	SE/1.8	--	SE/2.6	SE/1.5
Feb	WNW/1.9	SE/2.2	--	SE/2.2	SSE/1.4
Mar	SSW/3.2	SSE/3.2	--	SE/3.3	SSE/2.5
Apr	WNW/3.7	SSE/3.8	--	WNW/3.8	WNW/3.0
May	WNW/3.5	SSE/3.1	--	SE/3.6	NW/2.8
June	WNW/3.6	SSE/3.6	NNE/2.8	SE/3.8	SSE/2.9
July	WNW/3.3	SSE/3.2	N/2.5	SE/3.4	SSE/2.6
Aug	SSE/3.0	SSE/2.8	NNE/1.9	SE/3.4	SSE/2.2
Sept	SSE/2.9	SSE/2.1	NNE/1.9	SE/2.8	SSE/2.1
Oct	SE/2.5	SE/1.7	NNE/1.4	SE/2.6	SSE/1.7
Nov	W/2.2	SSE/1.7	NNE/1.5	SE/2.3	SSE/1.5
Dec	W/2.1	SE/.9	N/1.2	SE/2.1	SSE/1.3
Annual	WNW/2.9	SSE/2.5	NNE/1.5	SE/3.0	SSE/2.1

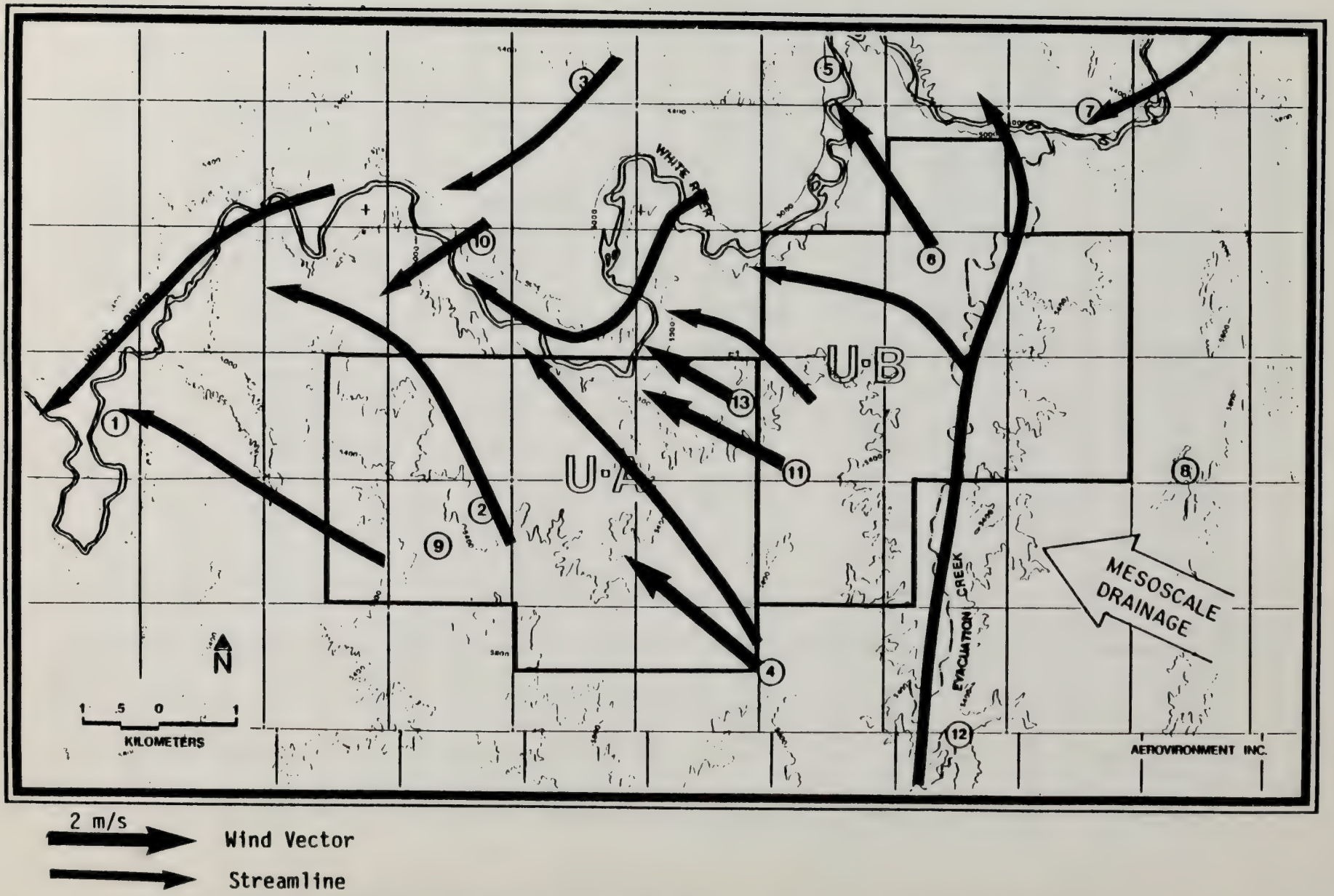


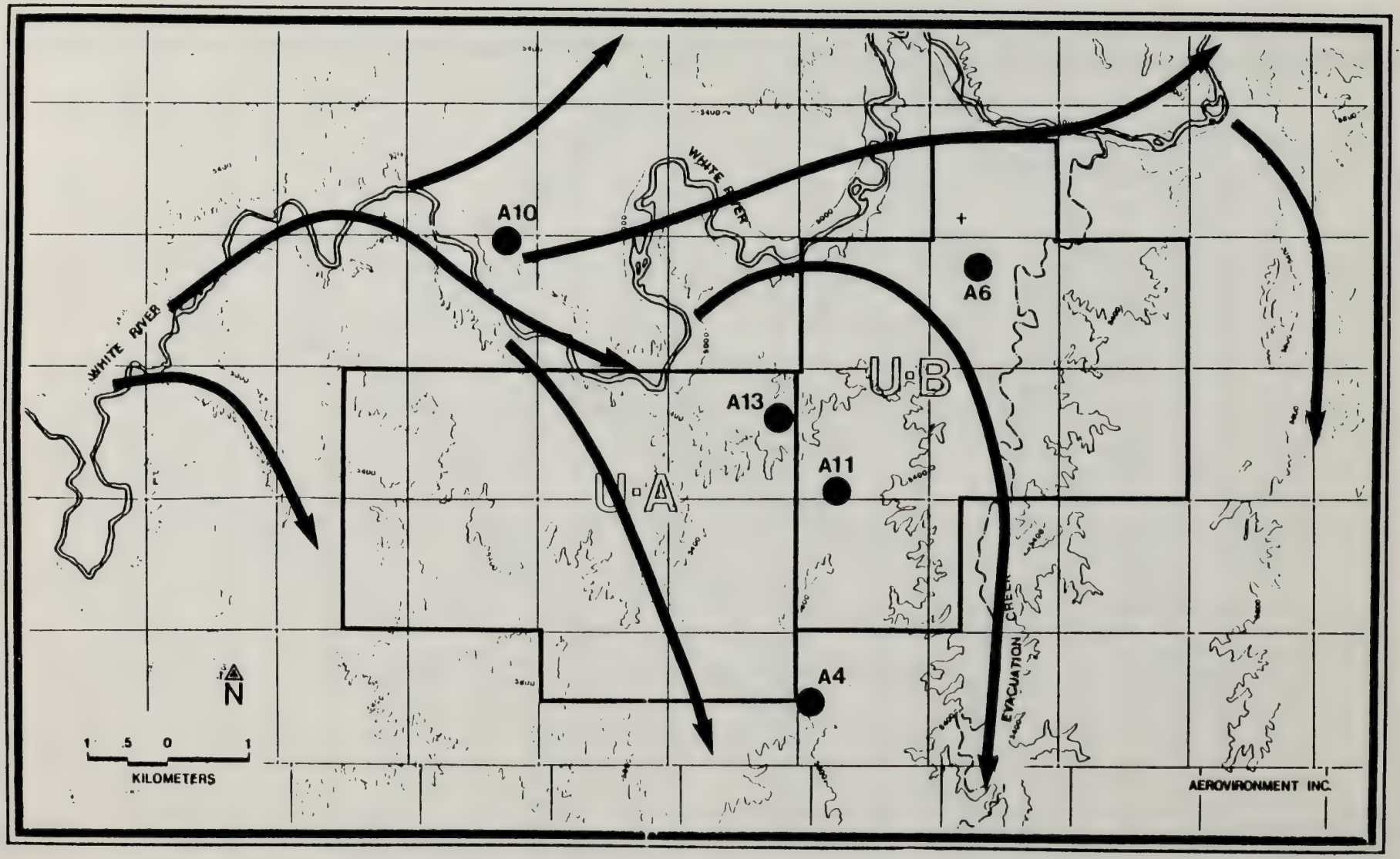
FIGURE 2.4-9. Typical drainage flow pattern on Tracts Ua and Ub during the early morning hours.

Figure 2.4-10 shows an upslope pattern that is transitional between drainage and synoptic flow. The surface-based inversion that results from strong radiative cooling begins to lose some of its strength shortly after sunrise. As the morning progresses, the heat gained by the surface from solar radiation exceeds that lost by terrestrial radiation and the soil temperature rises, warming the air above. This creates a pressure difference resulting in upslope flow. This pattern is transitional and generally lasts less than an hour, but is important in understanding pollutant dispersion since plume fumigation would occur under this condition. Because of its brevity, this pattern is lost in the hourly-average wind direction. This pattern begins earlier during the summer months than during the winter when the sun rises later.

Figure 2.4-11 shows afternoon streamlines on the tracts during 1981. Very little directional difference is noted except the average speeds are higher during the summer. No significant difference from the baseline period is noted. This is the average synoptically-induced flow encountered in this portion of Utah throughout the year.

Figures 2.4-12 and 2.4-13 give the average hourly wind speeds for January and July 1982. Both January and July 1982 wind speeds were lower than the baseline averages. The maximum winds occur during the afternoon in the summer months.

Figures 2.4-14 through 2.4-17 show the directional wind roses at the monitoring stations on the tracts using the mid-month of the four seasons (January, April, July, and October 1982). Although individual months may show different prevailing directions, SSE and SE has been the



Streamline

FIGURE 2.4-10. Typical airflow pattern on Tracts Ua and Ub during the transitional period.

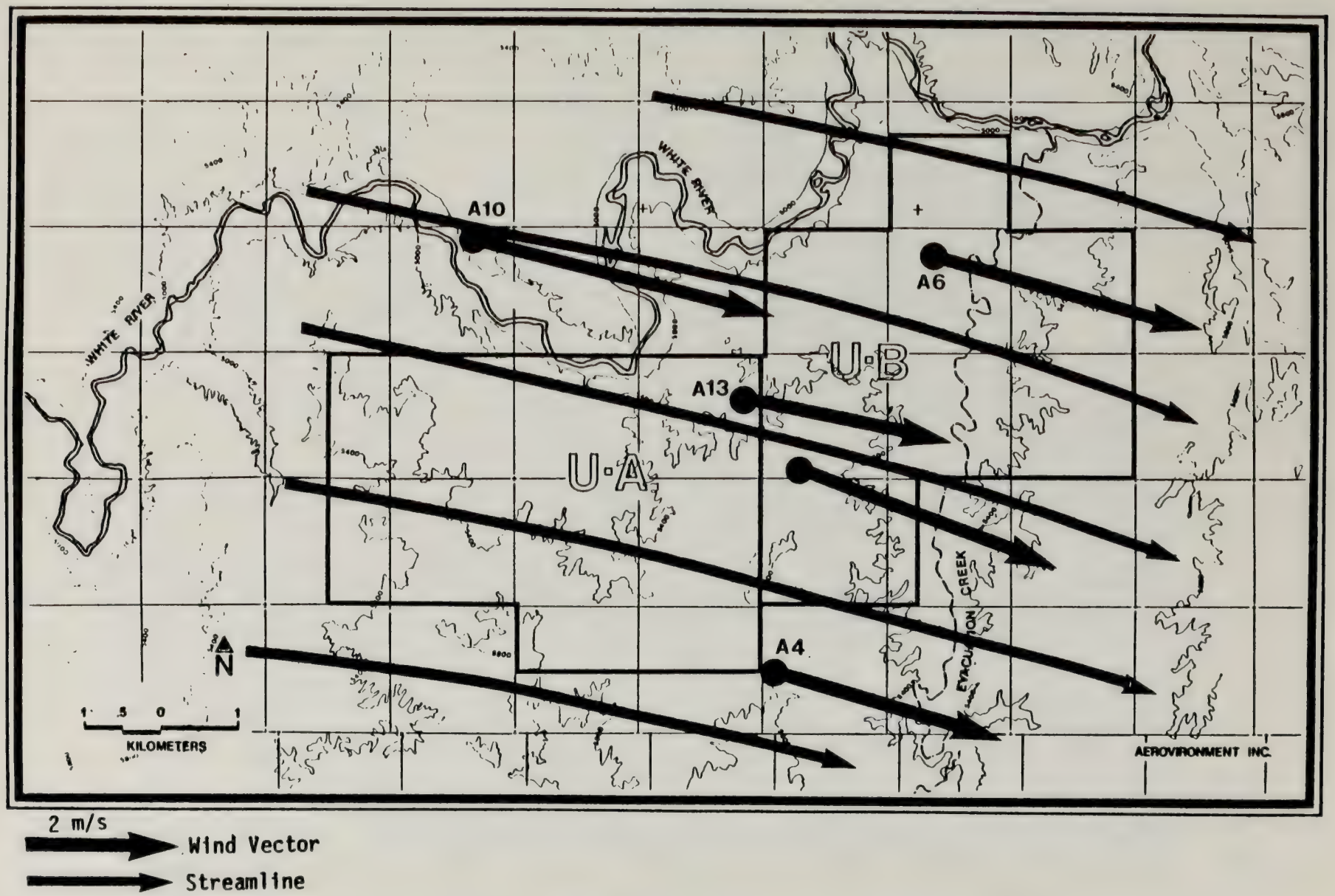


FIGURE 2.4-11. Typical synoptic airflow pattern on Tracts Ua and Ub during the afternoon.

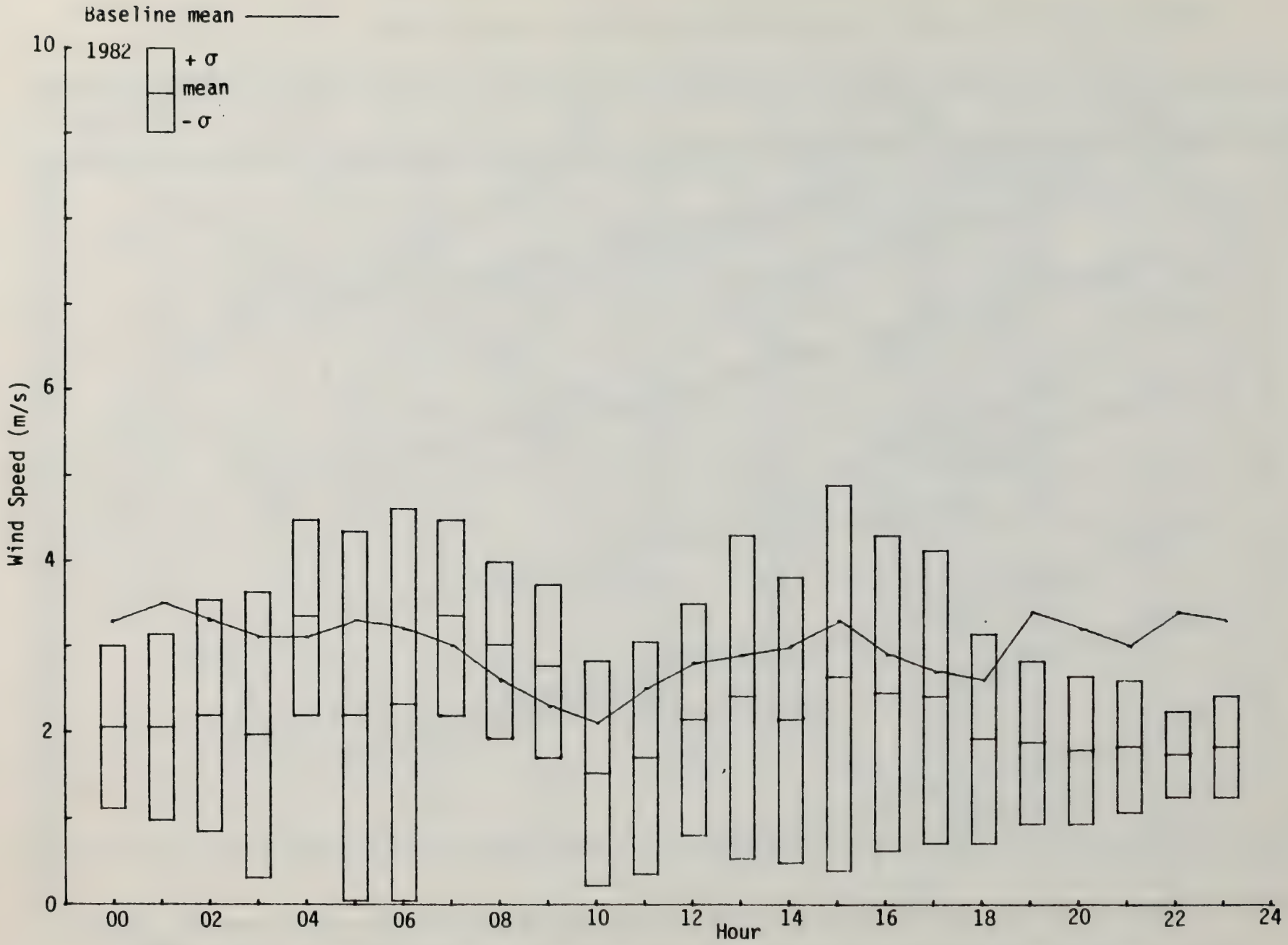


FIGURE 2.4-12. Diurnal variation of mean wind speeds and their standard deviations during January 1982 compared to the baseline means at Site A6.

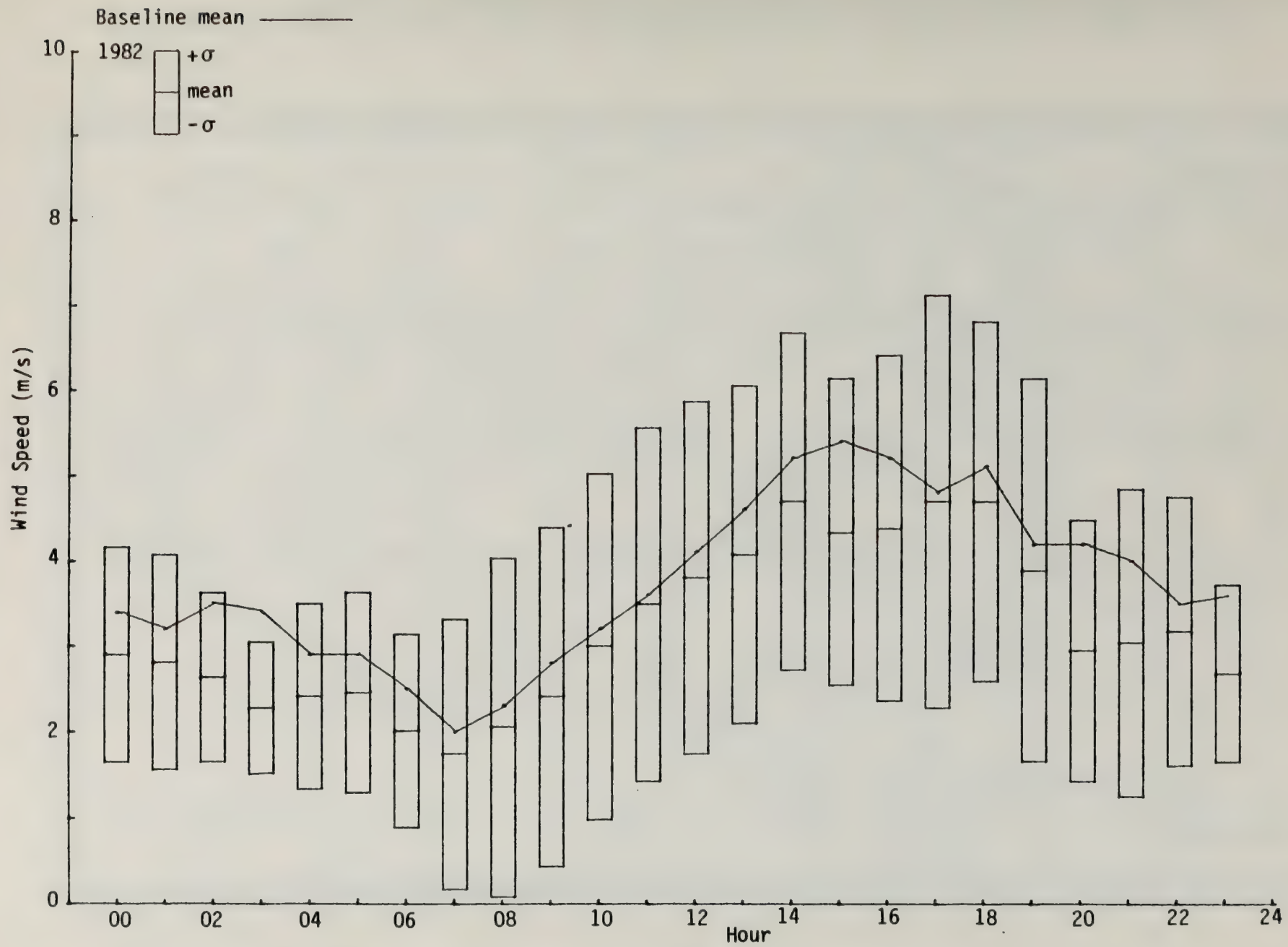


FIGURE 2.4-13. Diurnal variation of mean wind speeds and their standard deviations during July 1982 compared to the baseline means at Site A6.

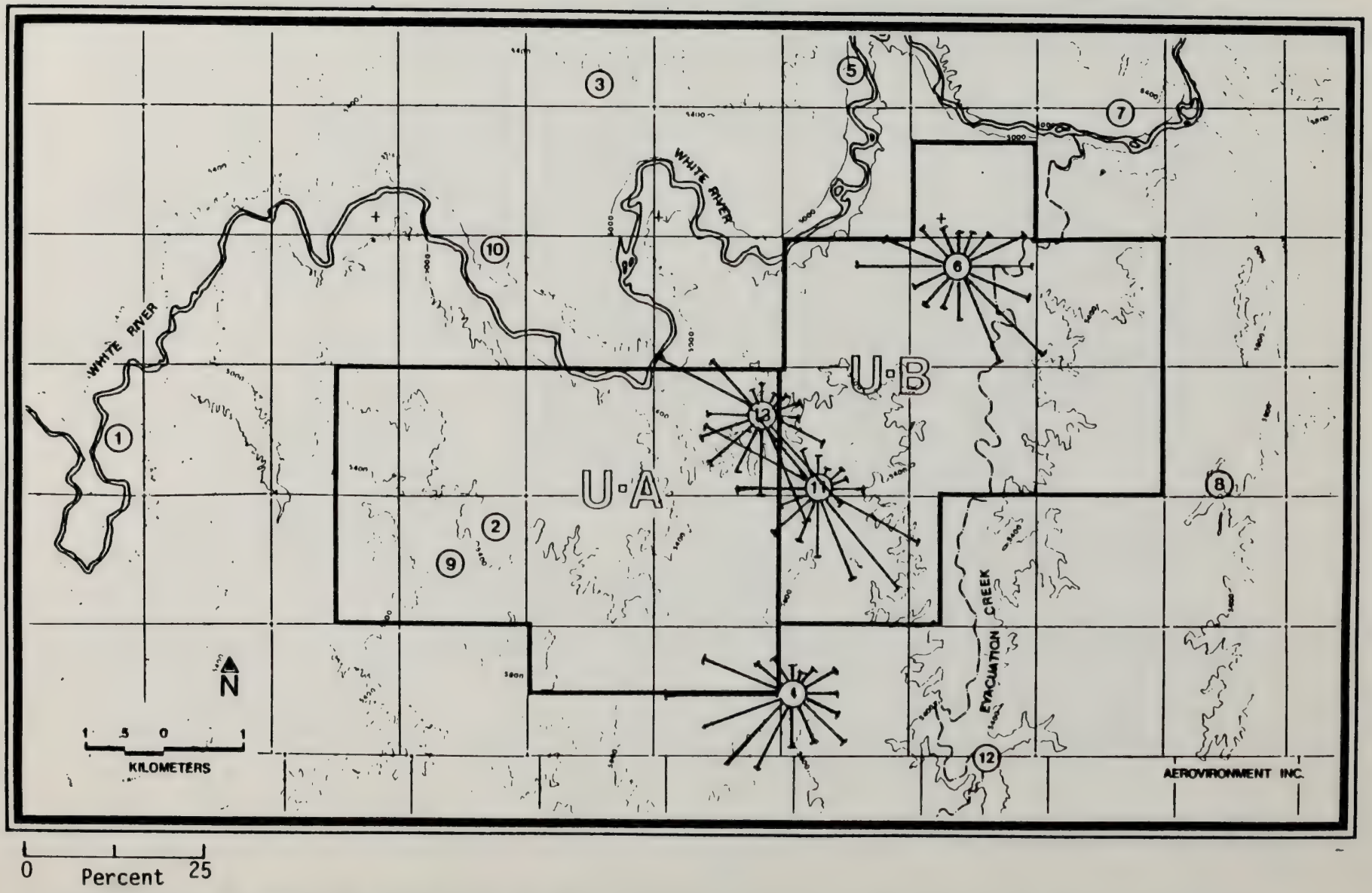
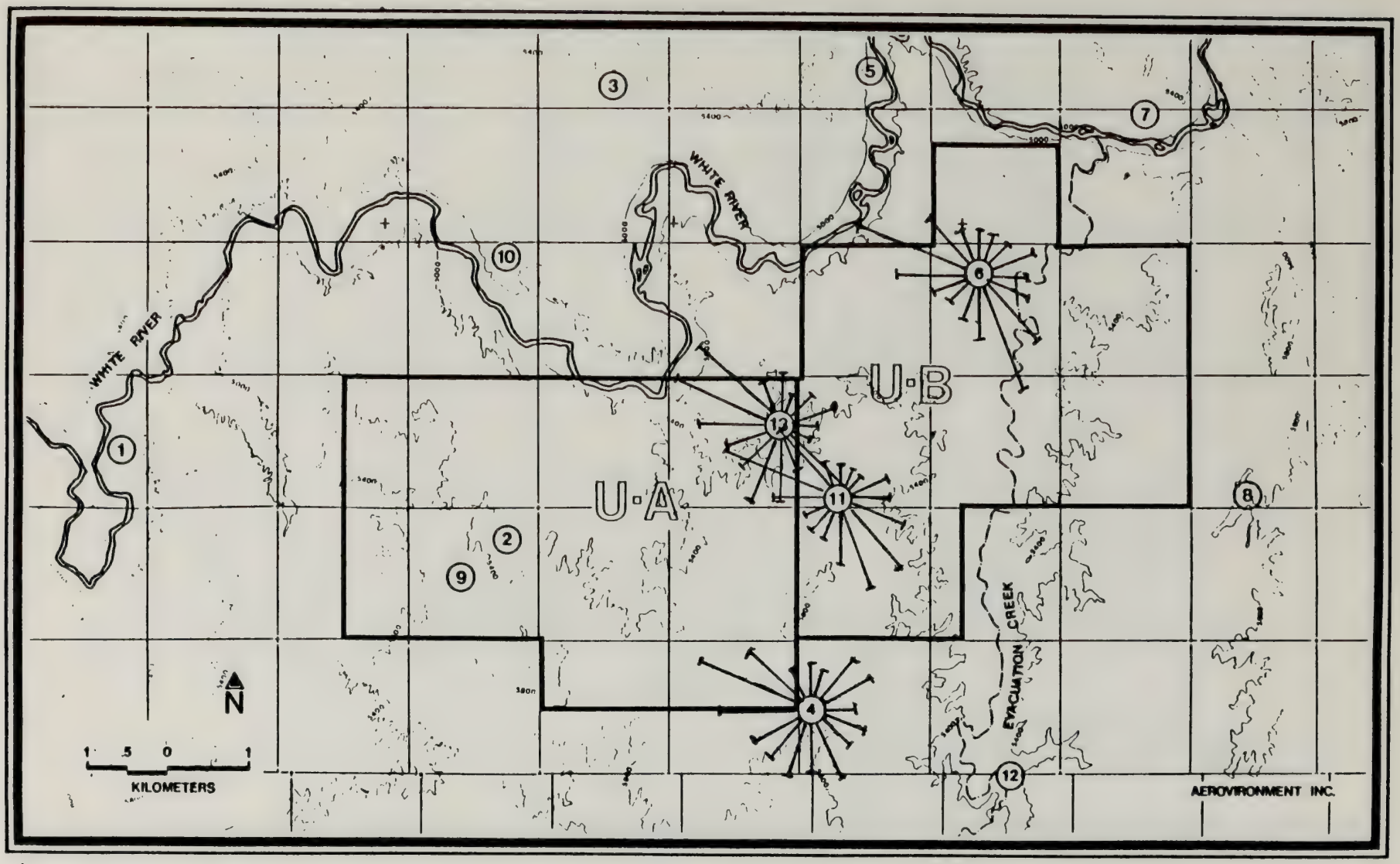


FIGURE 2.4-14. Directional wind roses at the monitoring stations on the tracts for January 1982. The length of each bar represents the frequency of winds from the direction towards which the bar points.



0 Percent 25

FIGURE 2.4-15. Directional wind roses at the monitoring stations on the tracts for April 1982. The length of each bar represents the frequency of winds from the direction towards which the bar points.

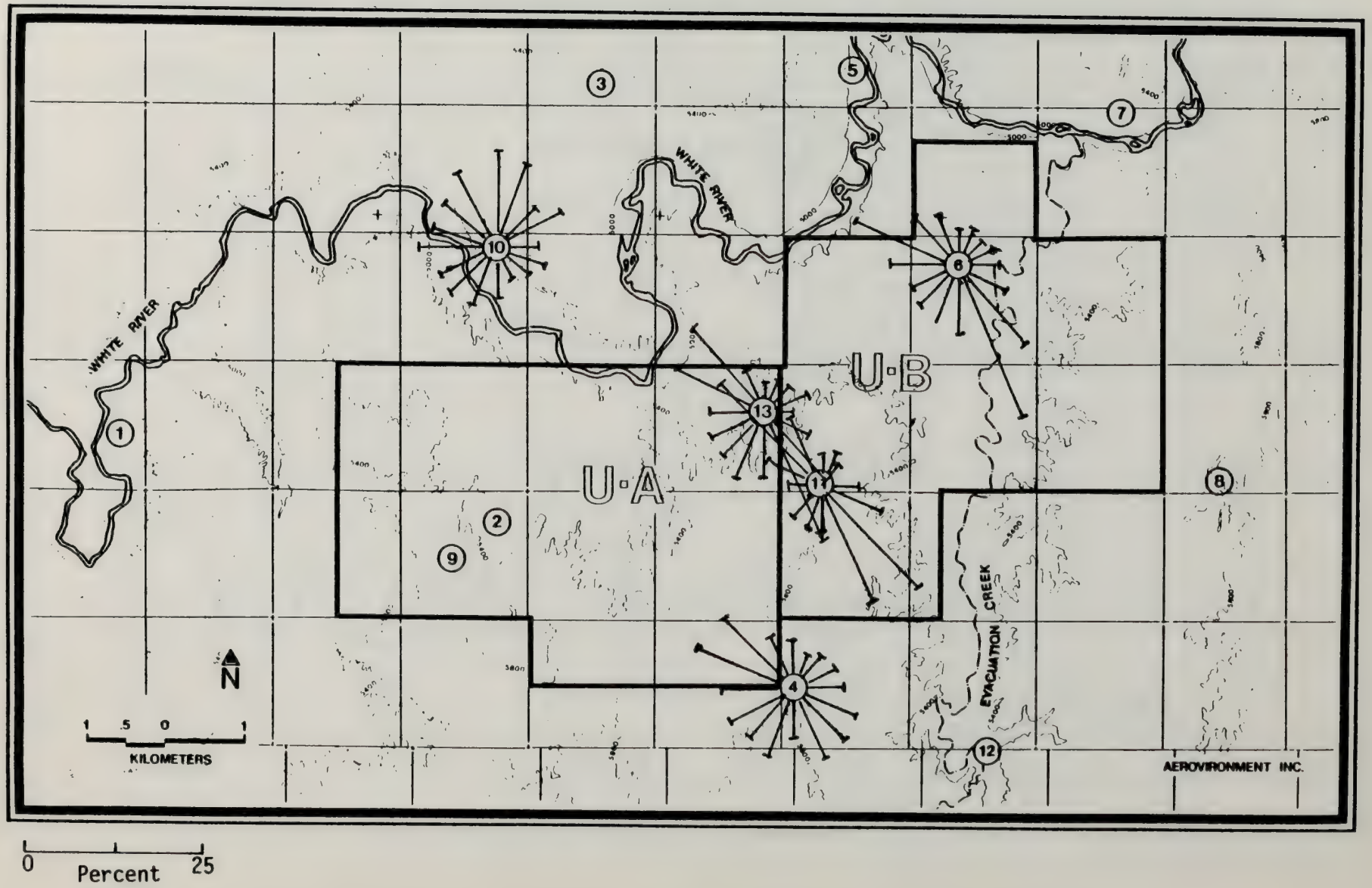


FIGURE 2.4-16. Directional wind roses at the monitoring stations on the tracts in July 1982. The length of each bar represents the frequency of winds from the direction towards which the bar points.

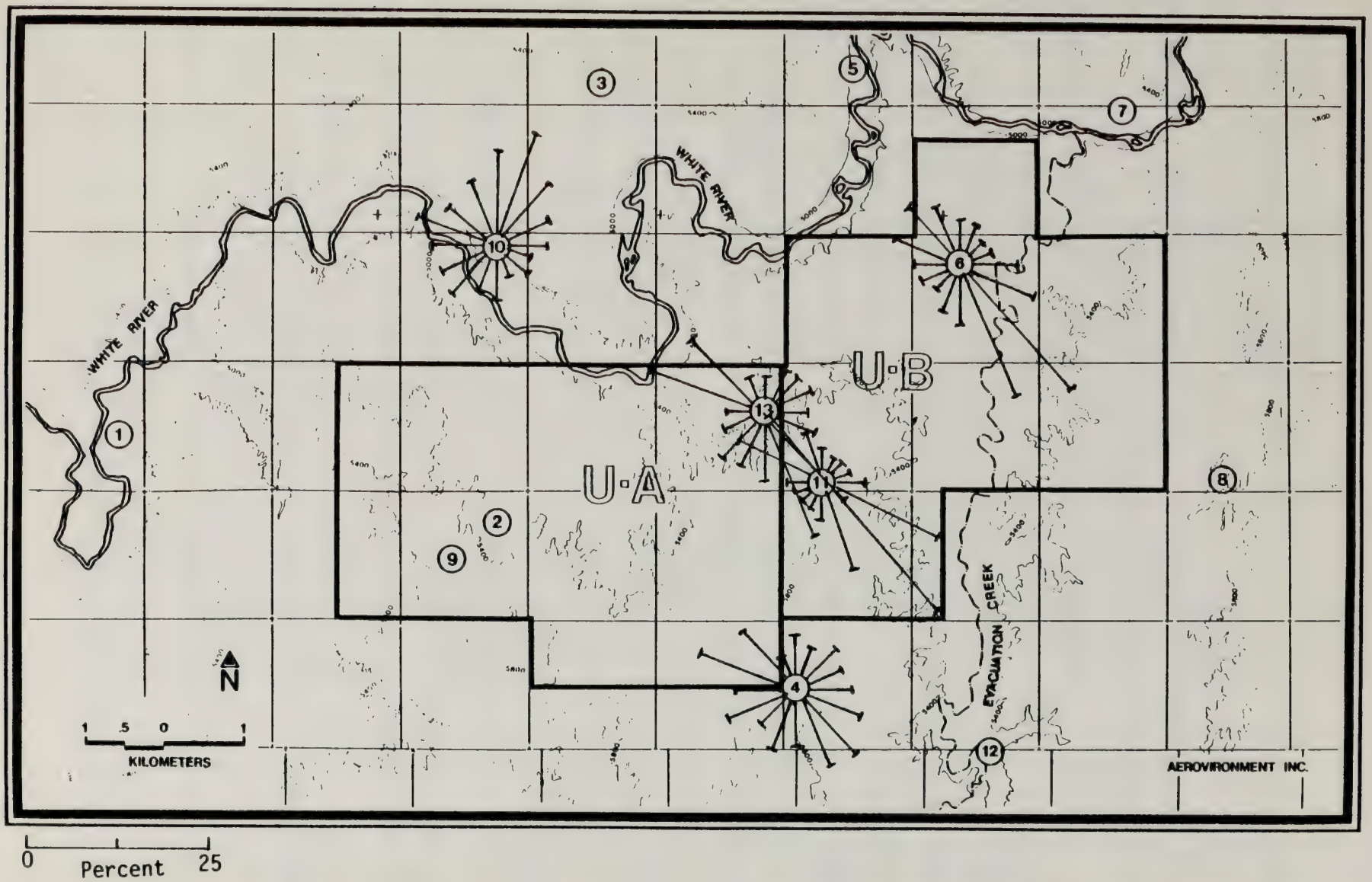


FIGURE 2.4-17. Directional wind roses at the monitoring stations on the tracts for October 1982. The length of each bar represents the frequency of winds from the direction towards which the bar points.

most prevalent direction at Site A6 throughout the baseline and interim periods. The frequent occurrence of this wind direction is a direct result of the drainage flow at Site A6. Site A4 shows prevailing direction from the Northwest because the drainage flow is weaker.

2.4.4.2 Temperature Figure 2.4-18 shows the diurnal variation in temperature and standard deviation for January and July 1982 at Site A6. Superimposed on this for comparison are the average baseline values. The daily maximum temperature was generally observed between 1400 and 1600 MST, while the daily minimum was observed between 0400 and 0700 MST. The average temperatures were -6° C for January 1982 and 24° C for July 1982. These are shown on Figure 2.4-19 along with the maximum, mean and minimum for each month in 1982 as compared to the maximum, mean and minimum for the baseline period. During the entire monitoring period, the highest July temperature observed was 36° C during July 1976, August 1979, and June at Site A6 and July 1982 at Site A4; the lowest temperature observed was -30° C during January 1979.

2.4.4.3 Relative Humidity The diurnal variation of relative humidity is approximately the reciprocal of temperature, indicating that the amount of moisture in the air remains fairly constant during the day on the tracts. Figures 2.4-20 and 2.4-21 show the diurnal trend of the average and standard deviations for a winter month (January) and summer month (July) at Site A6. Less storminess in January 1982 is reflected by the low relative humidity values compared to the baseline period. Relative humidity in July 1982 was also lower than the baseline average because of greater persistance of high pressure. The air is drier in summer than in the winter. The

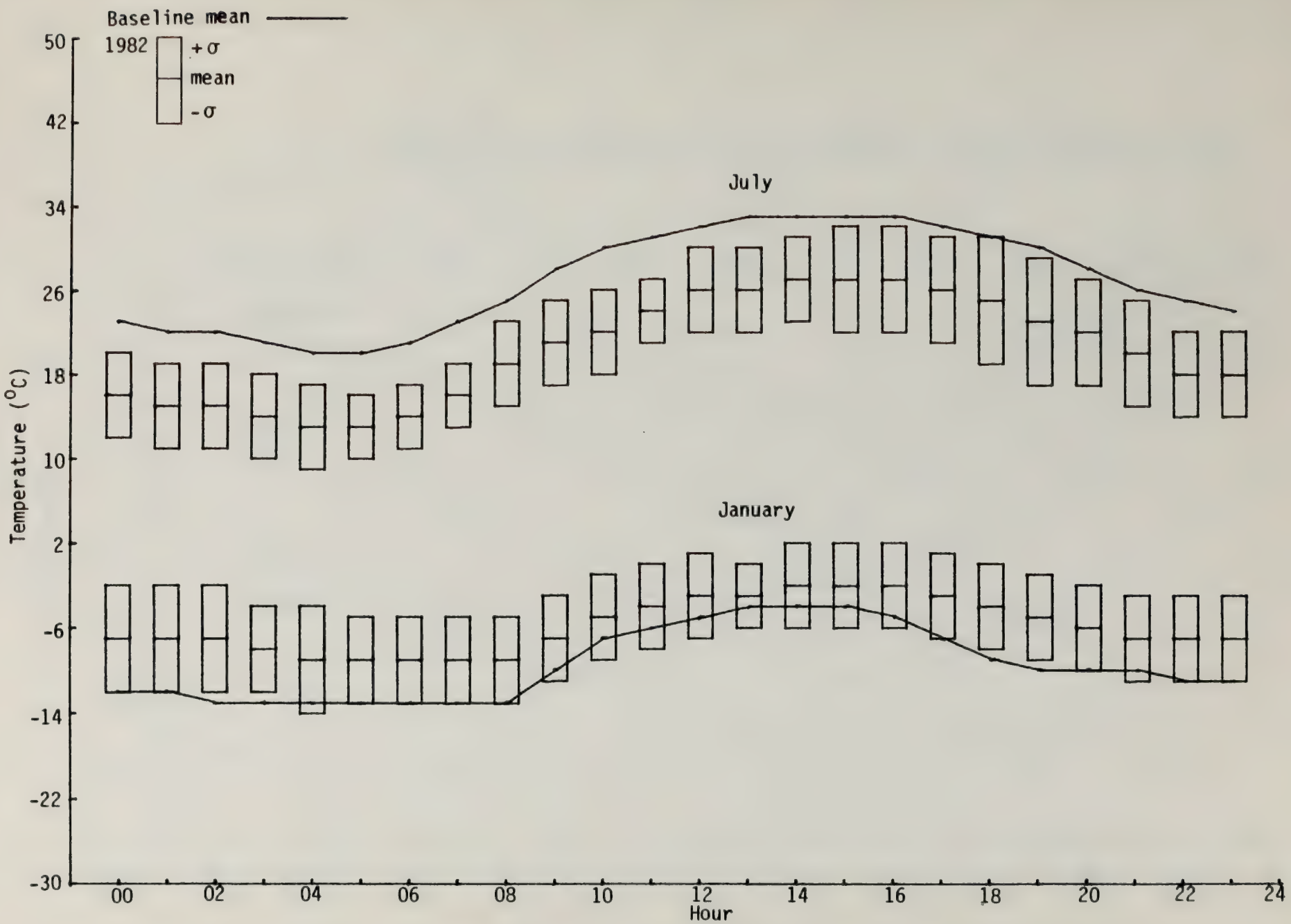


FIGURE 2.4-18. Diurnal variation of mean temperatures and their standard deviations compared to baseline means at site A6 during January and July 1982.

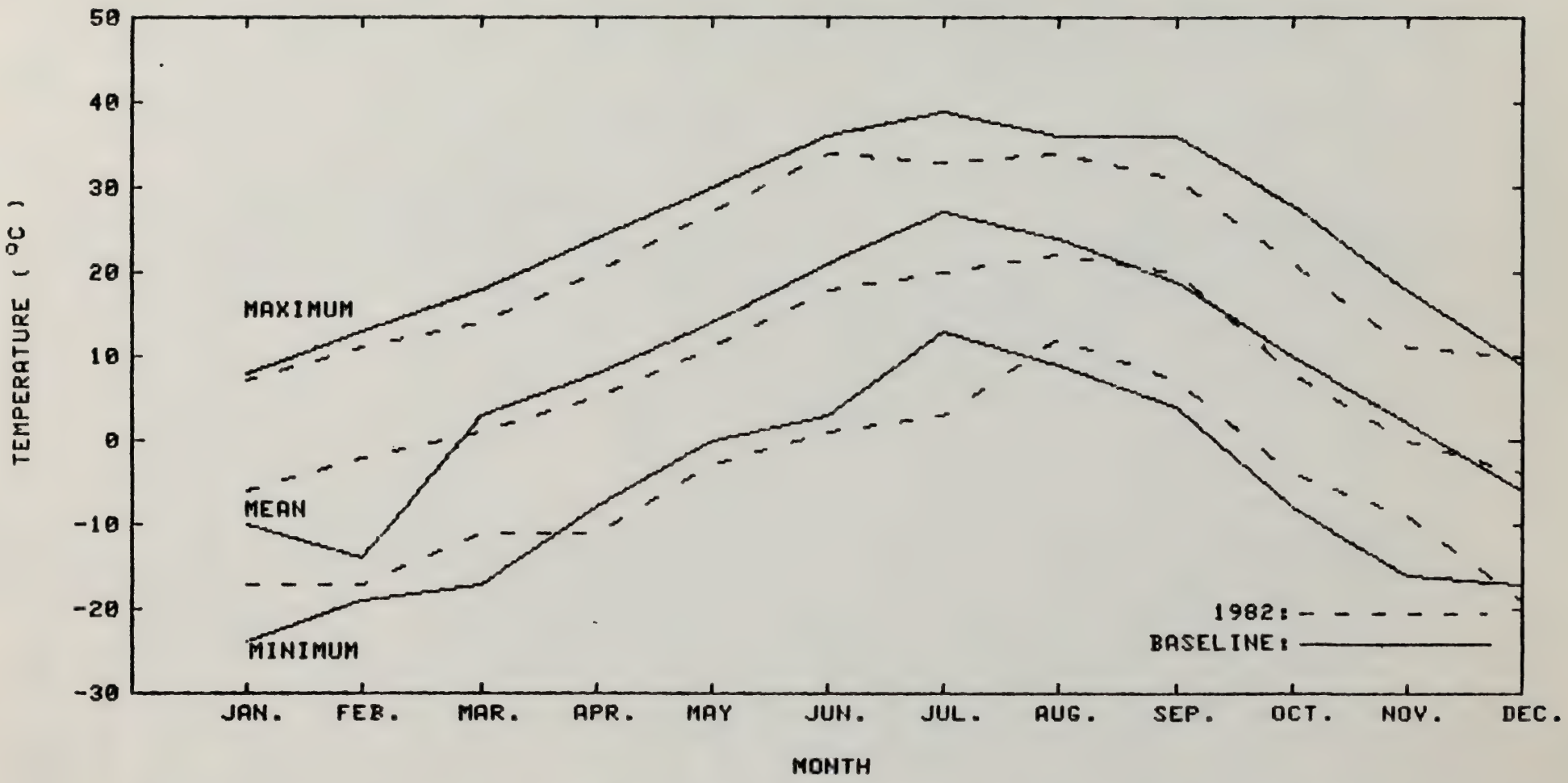


FIGURE 2.4-19. Monthly maximum, mean, and minimum temperatures at Sites A6 (January through June 1982) and A4 (July through December 1982) as compared to baseline values at Site A6.

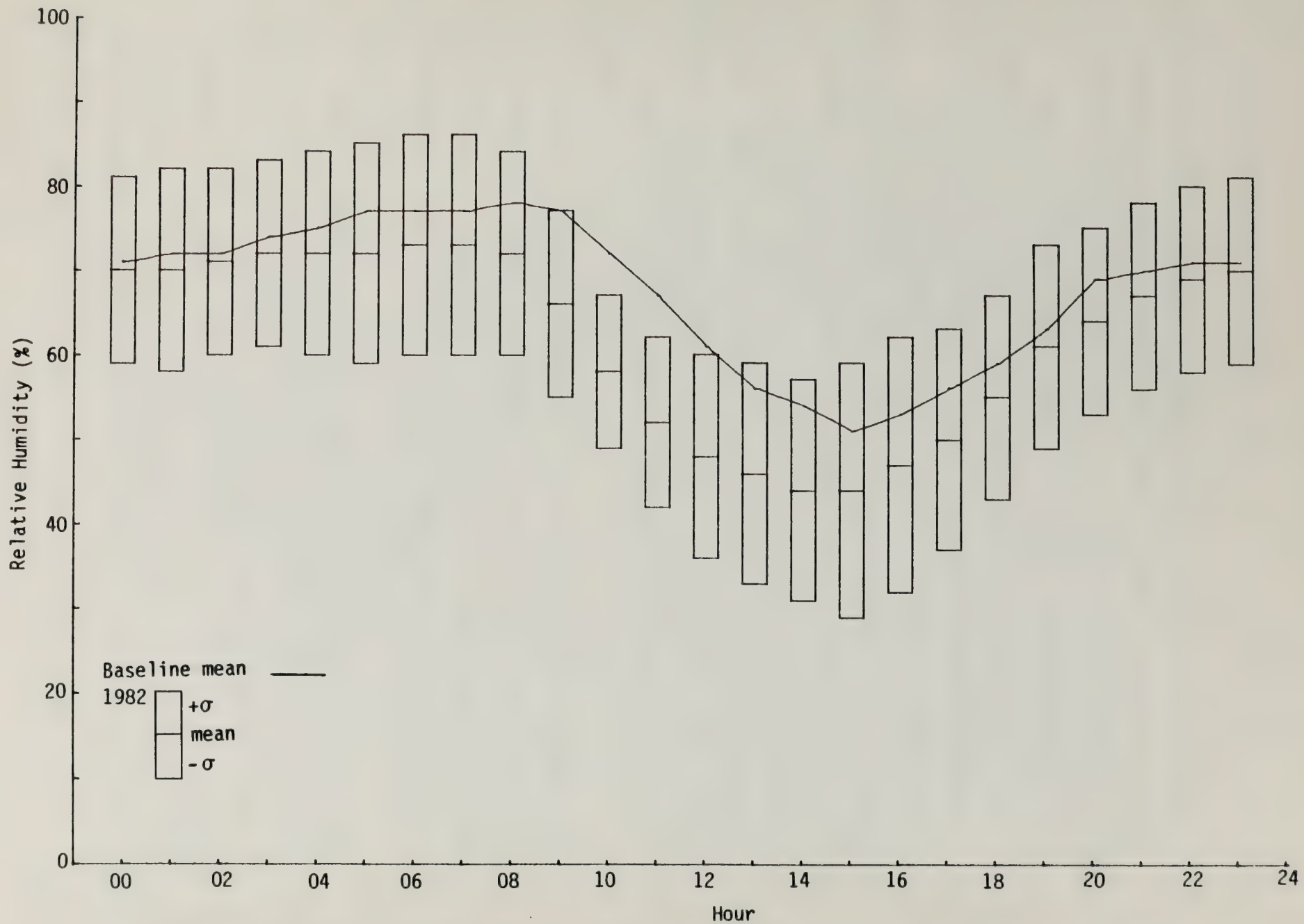


FIGURE 2.4-20. Diurnal variation of mean relative humdity readings and their standard deviation compared to the baseline means at site A6 during January 1982.

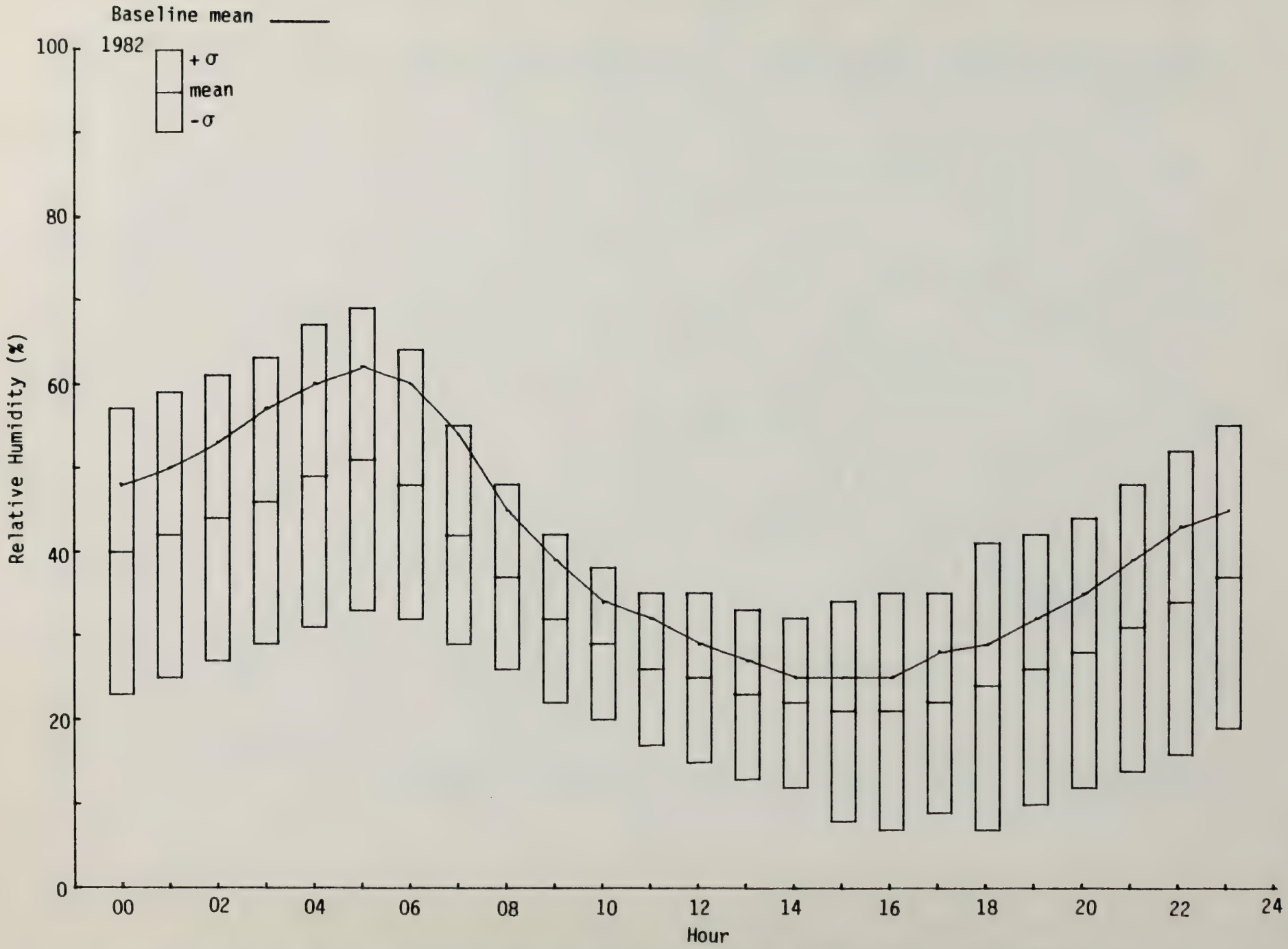


FIGURE 2.4-21. Diurnal variation of mean relative humidity readings and their standard deviations compared to the baseline means at site A6 during July 1982.

highest average readings are found in winter from 0400 through 0800 MST. The lowest values are found during summer afternoons between 1400 and 1600 MST. Table 2.4-13 shows the seasonal distribution of relative humidity at 0500, 1100, 1700, and 2300 hours for Site A6, (corresponding to the reporting times of the National Weather Service). On an annual basis, relative humidity in 1982 was slightly less than the baseline average.

2.4.4.4 Barometric Pressure Figure 2.4-22 gives the mean monthly barometric pressure as well as the maximum and minimum monthly barometric pressure at Site A6 for 1982. The highest value observed was 644 mm of Hg during January 1982, and the lowest value was 615 mm of Hg, also during January 1982. The winter storms cause the lowest readings and the basin highs bring the highest readings. During the summer the air mass systems are much weaker and, consequently, not much change in the pressure is evident.

2.4.4.5 Net Thermal Radiation Figure 2.4-23 shows the average hourly net thermal radiation at Site A6 during January and July 1982. As expected, the radiation is higher in the summer due to the longer days, more intense sunlight, and less cloudiness. Highest values during the day generally occurred around noon.

2.4.4.6 Diffusivity When a gaseous pollutant in the form of a plume or puff is released into the atmosphere it is transported by the prevailing wind. As it travels downwind its concentration decreases as its volume increases. Its growth in the vertical is governed mainly by the atmospheric stability, while its growth in the horizontal depends not only upon stability but on mechanical turbulence. Mechanical turbulence is defined as irregular

TABLE 2.4-13. Seasonal relative humidity (in %) at site A6 for 1982 compared to the baseline average.

Season	Hour							
	0500		1100		1700		2300	
	Baseline	1982	Baseline	1982	Baseline	1982	Baseline	1982
Winter	83	77	65	51	55	50	77	72
Spring	72	64	45	35	37	29	62	52
Summer	58	57	39	31	25	27	42	44
Fall	65	77	39	47	32	46	53	68
Annual	70	68	47	41	37	38	59	59

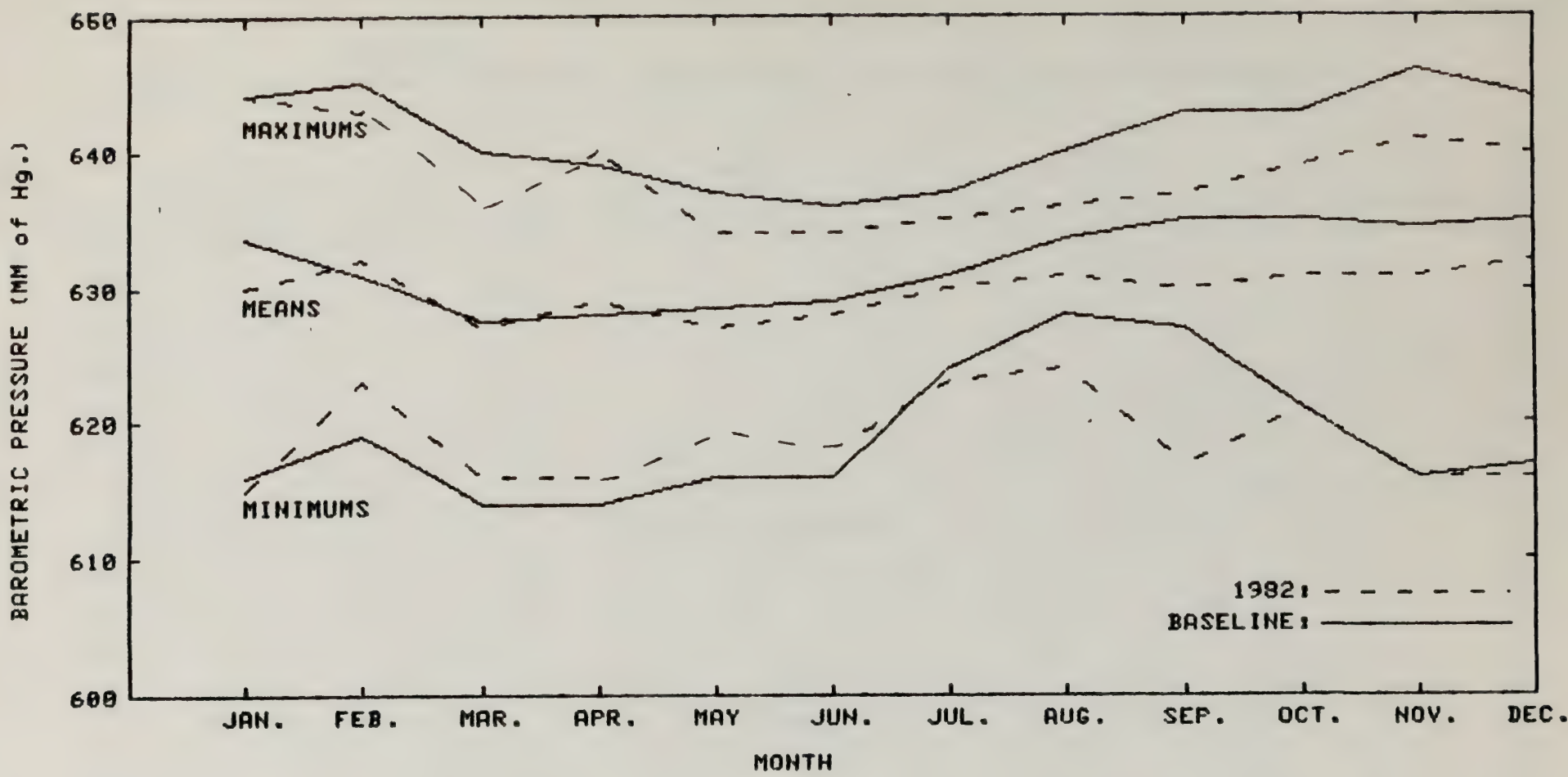


FIGURE 2.4-22. Monthly maximums, means, and minimums of barometric pressure at Site A6 during 1982 compared to baseline.

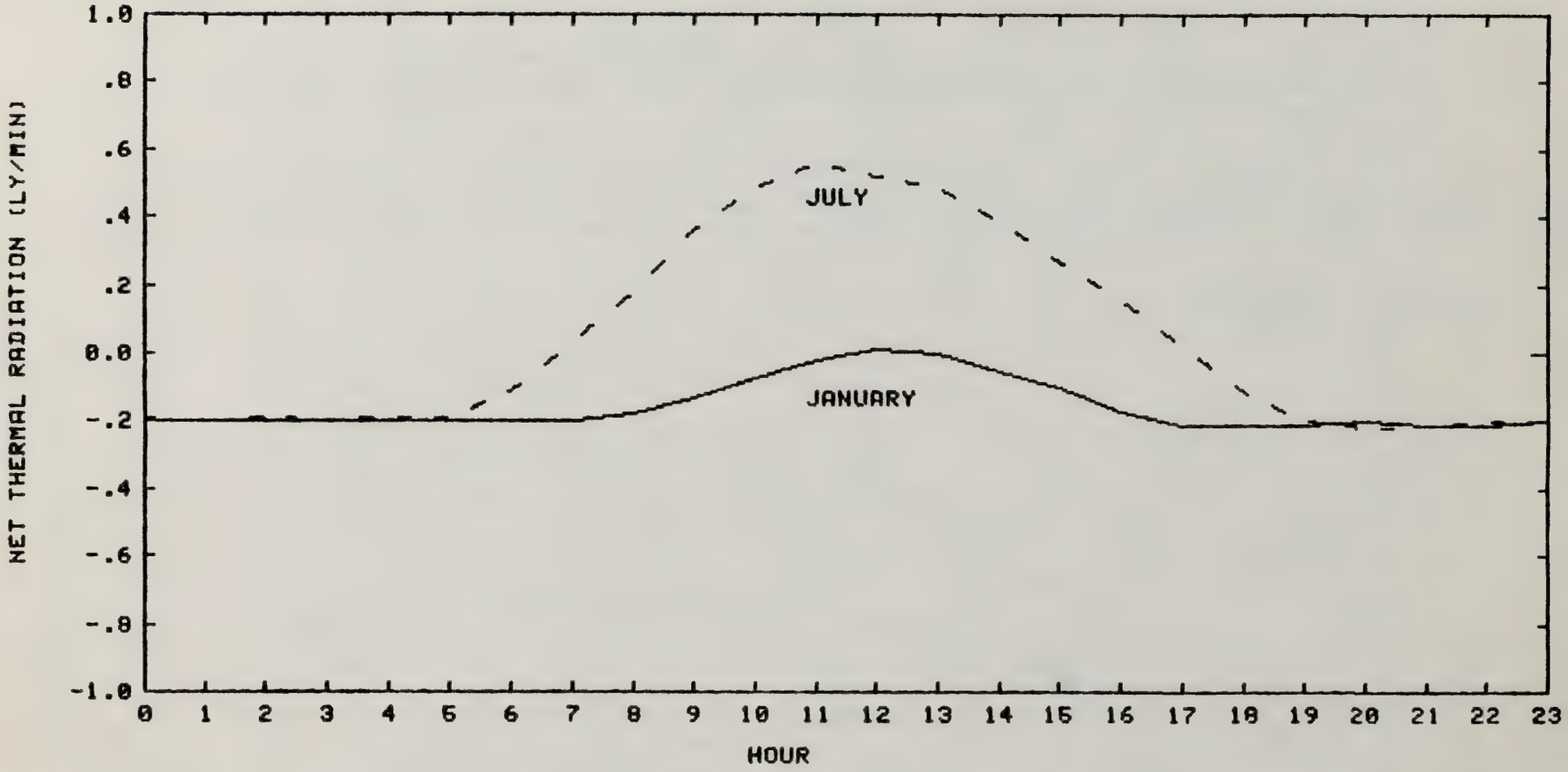


FIGURE 2.4-23. Diurnal variation of mean net thermal radiation at Site A6 during January and July 1982.

airflow induced by surface roughness. A surrogate of mechanical turbulence is the fluctation of wind direction, or sigma theta.

Using σ_θ data from Site A6, the frequency distribution of different "stability" ("diffusion") classes is computed in Table 2.4-14. The classification scheme used follows that in the Atomic Energy Safety Guide 23 (AEC, 1972) and appears in Table 2.4-15.

When the entire year is considered, stability Classes D and E are the most prevalent and the unstable classes (A, B, and C) account for 20% of the values.

A complete dispersion picture must also include the effect of plume rise. The meteorological parameters that greatly influence the height of a plume are vertical atmospheric (thermal) stability and wind speed. Vertical atmospheric stability can be best defined by ΔT data. In equations derived by Briggs (1974) for calculating plume height, only three atmospheric stability classes are needed. The classification scheme is listed in Table 2.4-16.

Figures 2.4-24 and 2.4-25 show the diurnal variation of ΔT collected at Site A6 for two months, January (winter) and July (summer) 1982. Because of the general cloudiness in January, the development of strong nocturnal stability was prohibited. Therefore, there was only a small diurnal variation in the mean ΔT and the stability was almost always slightly stable or neutral throughout the entire day. Very stable or slightly stable atmospheric conditions prevailed in early morning and evening during July. In the afternoon, neutral or unstable conditions were a general rule.

TABLE 2.4-14. Relative frequency distribution (%) of stability classes using σ_θ at Site A6 during 1982. Table 4.2-15 defines the classes A through G.

Season	Stability Classes							Total Number of Observations
	A	B	C	D	E	F	G	
Winter	0.1	2.3	11.5	36.9	34.9	8.5	5.8	1979
Spring	0.2	3.2	18.0	44.5	30.5	3.5	0.1	2189
Summer	0.2	5.1	21.6	38.9	30.4	3.1	0.7	2176
Fall	0.6	4.4	12.0	31.7	35.4	12.1	3.8	1120
All Year	0.3	3.7	15.8	38.0	32.8	6.8	2.6	7464

TABLE 2.4-15. Classification of atmospheric stability using σ_θ.

Stability Classification	Pasquill Categories	σ_θ* (degrees)
Extremely unstable	A	25.0
Moderately unstable	B	20.0
Slightly unstable	C	15.0
Neutral	D	10.0
Slightly stable	E	5.0
Moderately or very stable	F	2.5
Extremely stable	G	1.7

Source: Atomic Energy Safety Guide 23 (AEC, 1972)

*Standard deviation of horizontal wind direction fluctuation over a period of 15 minutes to one hour. The values shown are averages for each stability classification.

TABLE 2.4-16. ΔT stability scheme.

Stability	ΔT ($^{o}C/100m$)
1. Unstable and Neutral	<-0.5
2. Slightly Stable	-0.5 to 1.5
3. Very Stable	>1.5

Source: Briggs, 1974

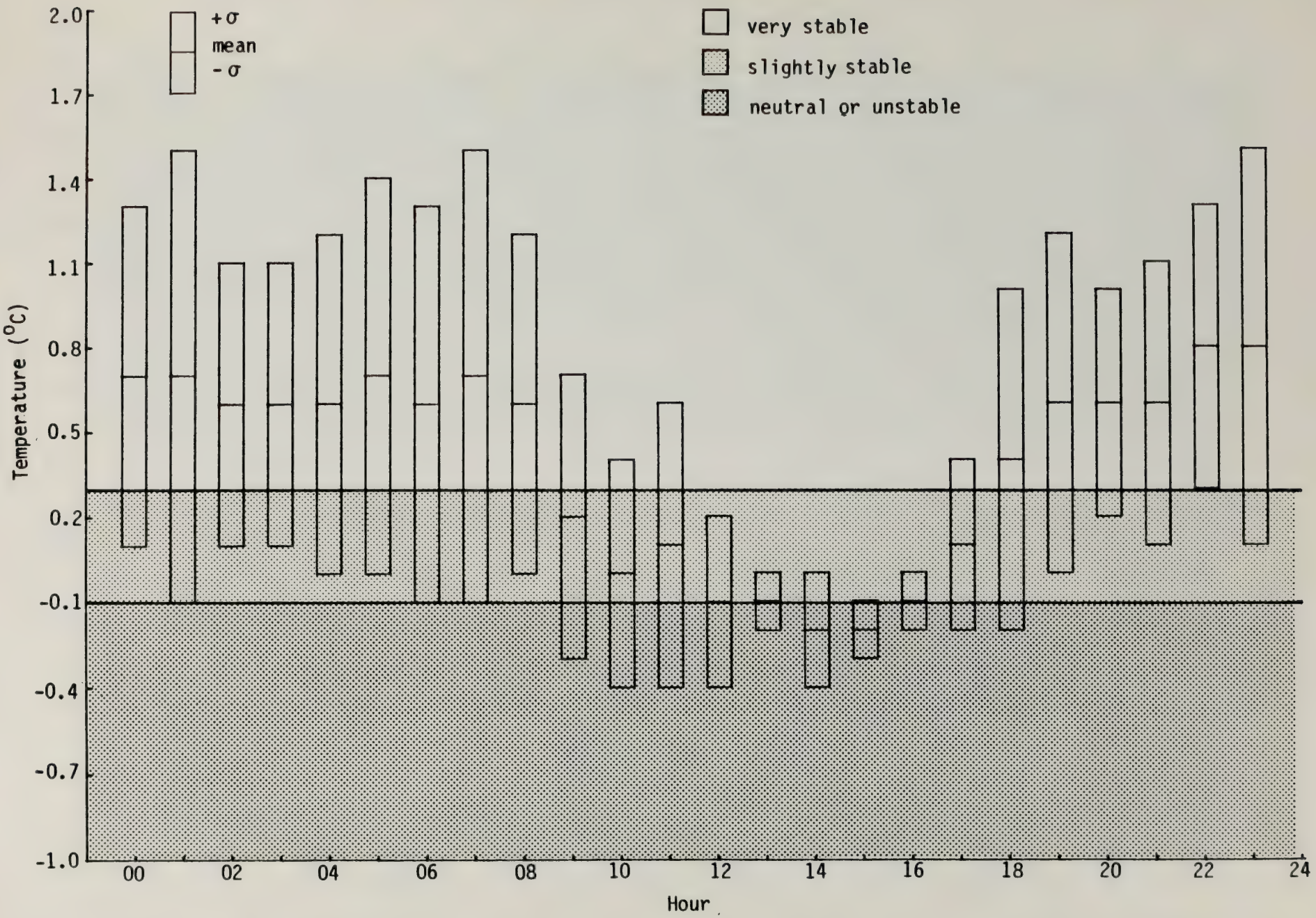


FIGURE 2.4-24. Diurnal variations of the mean ΔT and their standard deviations at site A6 during January 1982.

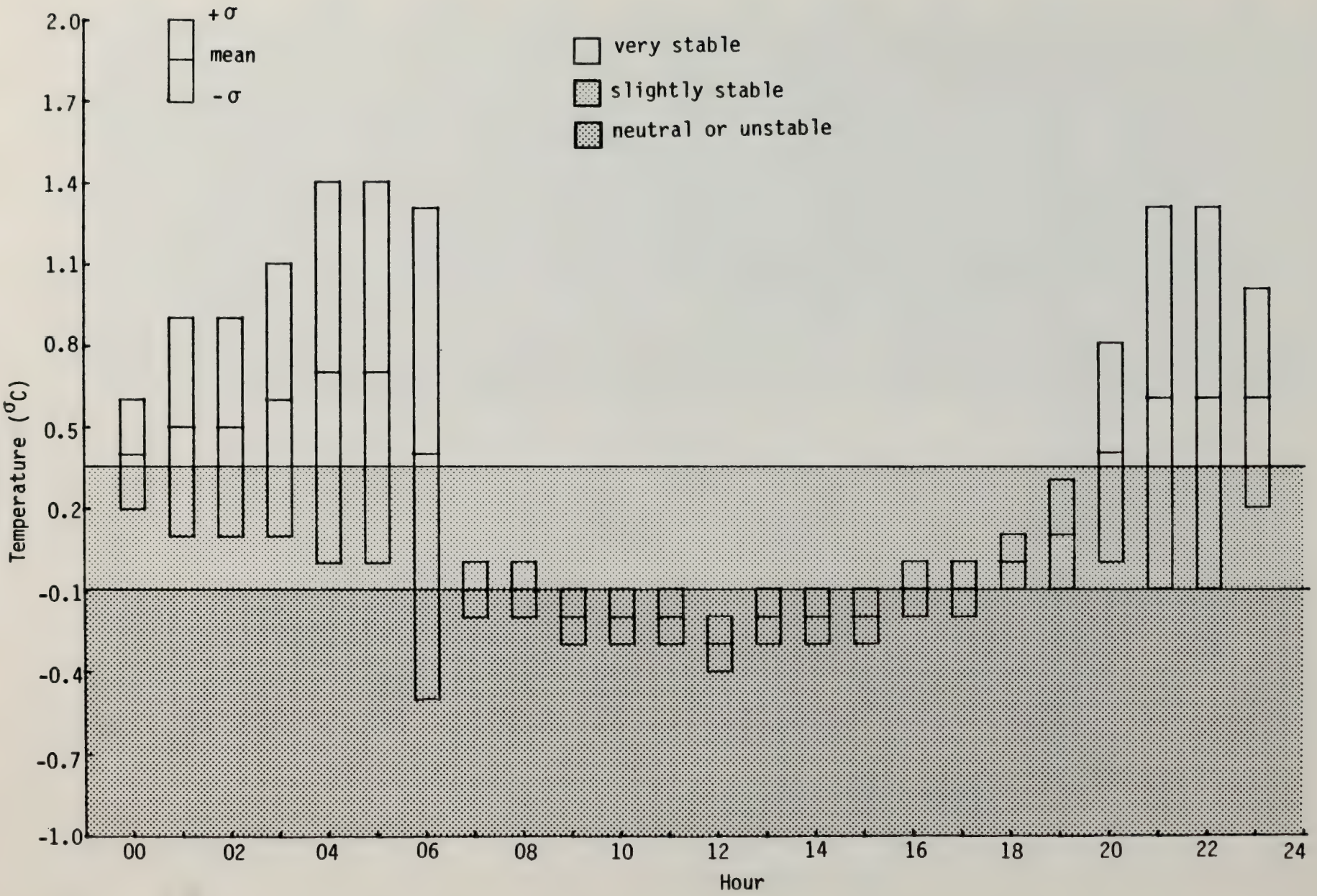


FIGURE 2.4-25. Diurnal variations of the mean ΔT and their standard deviations at site A6 during July 1982.

The frequency distribution of stabilities for each season based on ΔT appears in Table 2.4-17. This table shows that very stable conditions occurred more often during fall and winter. Unstable or neutral activities occurred during the spring. The instrument for 1982 measures ΔT to within $\pm$ 0.1^{o}C 20 meters over the measurement interval. Accuracy was below this level in the baseline period; hence, no comparison of the ΔT data is attempted.

Over the entire set of joint frequency distributions, the combination of very stable atmosphere ($\Delta T > 1.5^{o}C/100$ m) with low wind speeds (< 3.5 m/s) occurred 29% of the time during 1982, with such occurrences most frequent, ~41%, in the winter. Table 2.4-18 shows the relative frequencies of such occurrences by seasons for 1982.

2.4.5 Sound Levels

Sound level measurements show, as expected, that the Ua and Ub area sound levels were low (24-26 dB(A) with no wind at sites away from the White River) and uniform from season to season. Noise sources were primarily natural (such as insects, running water, rustling grass, wind). Background levels near the White River ranged from approximately 30 dB(A) to 60 dB(A) in moderate wind.

These measurements were resumed in October 1981 to update the baseline sound levels before construction begins. The typical background noise levels in 1982 were between 20 to 30 dB(A) and the highest value was 74 dB(A) at the Ignacio site when several bulldozers were operating.

The background (natural) noise levels measured are very dependent upon winds. Water running in the White River is a more localized source of natural noise. Areas closer to these sources are correspondingly noisier.

TABLE 2.4-17. Relative frequency distribution (%) of ΔT at Site A6 for 1982.

Season	Stability (ΔT in $^{o}C/100m$)			
	Unstable or Neutral (<-0.5)	Slightly Stable (-0.5 to 1.5)	Very Stable (>1.5)	Total Number of Observations
Winter	35	23	42	1450
Spring	47	31	22	2209
Summer	29	40	31	1325
Fall	31	30	39	640
All Year	36	31	33	5624

TABLE 2.4-18. Relative frequency (%) of low wind speed (<3.5 m/s) combined with very stable (>1.5°C/100 m) atmosphere for each season in 1982 at Site A6.

Season	Frequency (%)	Total Observations
Winter	40.8	591
Spring	20.4	451
Summer	25.9	343
Fall	29.4	188
All Year	29.1	1573

On the tracts, noises from human activities add to the natural background. Along roads the increase is greater, as expected. Vehicles account for the highest sound level measurements.

2.5 REFERENCES

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VEGETATION RESOURCES

3.0 VEGETATION RESOURCES

3.1 INTRODUCTION

The following section discusses the vegetation monitoring studies conducted during 1982 by Native Plants, Inc. under contract to WRSOC. The vegetation monitoring program under the direction of Dr. Cyrus McKell incorporates data from the 1975-76 baseline studies with the data collected on Tracts Ua and Ub since that time. There has been a concerted effort to document existing conditions and determine interactions between the vegetation and abiotic and biotic factors on the tracts. The vegetation monitoring program affords two important advantages:

- o documentation of vegetation responses to natural fluctuation or variation, that could otherwise be interpreted as impacts of development; and
- o identification of problems early before they become serious, enabling corrective measures or contingencies to be initiated prior to any irreversible environmental damage.

The vegetation monitoring program is also designed to provide data that describes the possible effects on the vegetation community caused by oil shale mining, processing and disposal of the retorted shale. The array of vegetation-related parameters used in monitoring includes key vegetation-related characteristics that are vital to ecosystem function. The characteristics are sensitive to immediate impacts of development or to cumulative influences plus interactions with affected ecosystem processes. The monitoring program includes variables that are indicative of environmental health and responsive to environmental impact.

3.2 SUMMARY

The vegetation monitoring program was composed of eight interrelated tasks that are designed to document existing conditions, determine and quantify interaction between the vegetation and abiotic and biotic factors, and provide a means of identification of impacts on the vegetation by development. A summary of the results for 1982 for each of those eight components follows.

3.2.1 Production of Annual Plant Biomass

Production of Annual Plant Biomass was relatively high in 1982 with the total of all four community types averaging 28.7 gm/m^2. This was lower than only 1975, 1978 and 1979, which had 217.3, 30.5 and 30.6 gm/m^2, respectively. The riparian vegetation type again had the highest biomass and cover of the four vegetation types considered, averaging 68.1 gm/m^2 and 18.2%. The Juniper type had the lowest biomass and cover, averaging 0.4 gm/m^2 and 0.2%. The Shadscale type averaged 24.7 gm/m^2 for production and 6.4% for cover, while the Sagebrush-Greasewood areas averaged 21.4 gm/m^2 for production and 5.5% cover. Precipitation records were compared with annual plant biomass data and production appears to be better correlated with October through May precipitation than strictly Spring (April-June) precipitation. Since these earlier months represent a period of soil water recharge, as well as the germination for most annuals, the October through May data would appear to be a better indicator of annual species success.

3.2.2 Sagebrush Leader Growth

Over the eight years of study, sagebrush stem growth ranged from 2.7 cm in 1977 to a high of 8.4 cm in 1979. The data for 1982 on sagebrush leader growth (4.8 cm) was the third lowest value recorded during this time period. An analysis of variance (ANOVA) was performed on the data (Sites 1-6) for the eight years of record. The results point out that there was a significant

difference between years. An ANOVA test comparing sites also showed significant differences. Site 3 had significantly longer stem lengths than any of the other sites.

Growing conditions for sagebrush in 1982 should have been very good for stem growth, but this is not generally reflected in the stem lengths data recorded. The variable of stem length is apparently highly correlated with fall-winter precipitation. The precipitation for the fall-winter period averaged 6.00 inches which was the second highest average recorded to 1979. Stem length was considerably below the value that would be predicted strictly by the regression equation but still within the 95% prediction interval.

3.2.3 Plant Chemical Composition

Sagebrush leaders from the seven sagebrush stem growth sites were analyzed for molybdenum, arsenic, sodium, calcium, magnesium, sulfates, mercury, cadmium and boron. These parameters were selected because they had the potential to accumulate in plant tissue as a result of industrial development. Values obtained from the analyses all show levels within the normal range of concentrations within plants. These values will serve as baseline data for later comparisons after the extraction plant is in operation.

3.2.4 Litterfall Measurements

A total of 242 litter traps were placed underneath seven dominant species of shrubs or trees, at locations scattered throughout the tracts to assess the amount of biomass returning to soil. The data on litterfall will serve as baseline in assessing the health and vigor of the dominant species in the area, as well as providing information on nutrients returning to the soil and food resources to many small animals. Litterfall was highest (on a weight per size index or volume) for shadscale at 174 gm/m^3. Sagebrush averaged 118.5 gm/m^3, followed by spiny hopsage (74.9 gm/m^3), greasewood (40.5 gm/m^3),

rabbitbrush (39.5 gm/m^3) and finally, fourwing saltbush (38.4 gm/m^3). Juniper litter traps were not equivalent to those traps used for the six shrub species and should not be compared with litterfall from these species. Litterfall under Juniper did decrease in 1982 (112 g/m^2) from 1981 (123 g/m^2) levels, however, the decrease was not significant.

3.2.5 Assessment of Animal Utilization of Plants

Animal use of shrubs was assessed using the Cole Browse Survey at six sites utilizing three key forage species. June 1982 data showed that sagebrush leader growth was browsed (66%) more than shadscale (47%) and greasewood (40%). In addition to the Cole Browse Survey Method to assess browse useage, 20 sagebrush plants were enclosed with chicken wire and in March 1983, caged and noncaged leader length will be measured to obtain better estimates of actual biomass taken by browsing animals.

3.2.6 Lichen Monitoring

During the 1982 field season, 21 permanent stands were located along the three transects radiating from the proposed plant site. At each stand a permanent photo plot was established and pertinent ecological data taken on the lichen community. The saxicolous lichen, *Lecanora peltata* was selected for elemental analysis.

Parameters found to be good indicators of current conditions and valuable for monitoring future impacts include total cryptogamic cover, number of species/quadrat and sulfur content of lichen tissue. The variability of the other parameters measured negated their use in a monitoring program such as the one designed for the White River Shale Project.

3.2.7 Plant Condition and Stress

Aerial Color Infrared (CIR) photographs were taken along three transects traversing the proposed plant site to determine the optimum scale for

detecting plant stress. Photographs were taken at two scales 1:6000 and 1:2400. The CIR photography at 1:2400 appears to be the most appropriate for monitoring vegetation stress on and near to the tracts. If a more dense vegetation was present, the photographs taken at 1:6000 would be advantageous in showing overall vegetation stress. However, due to the sparse vegetation, stress on individual plants must be detectable, which is more accurately accomplished with CIR photography at a scale of 1:2400.

During ground reconnaissance, stressed vegetation was marked on the photographs and, where possible, the casual agent noted. The stressed plants can be categorized at this point into two major groups; those resulting from a phenological stage and those showing casual agent, such as disease or mechanical disturbance.

3.2.8 Soil Microbiology and Soil Chemistry

Samples were taken along transects at eight sites within the four vegetation types recognized on the tracts. The sites were sampled five times (February, April, June, August, October) in 1982 to assess yearly fluctuations. Soil moisture content fluctuated from a high in February of 23.5% to a June low of 2.2%. Moisture levels were 1-2% higher in subsurface soils during summer months while the moisture levels of the surface soils are 5-10% higher during the winter. This yearly fluctuation and soil sample patterns were similar to results in 1981 although 1982 levels were 3-4% higher overall. Soil pH, organic carbon, and EC levels did not change significantly through the year. They all showed little differences between sites. EC levels did show a general 30% decrease for all sites from the 1981 analysis which is probably due to the increased precipitation during 1982, while pH and organic carbon readings for 1982 were very similar to 1981 data.

Soil bacteria fluctuated in an annual cycle characterized by a sharp winter high (8.90×10^6 CFU/g) and a summer low (2.5×10^6 CFU/g). Bacterial counts were 50% lower in subsurface soils (5-15 cms) than surface soils (0-5 cm). Fungal populations showed a general decline through 1982 continuing the declining patterns established in 1981. These results are unexpected and alternative sampling schemes have been initiated to validate the sampling technique.

Respiration rates showed an annual cycle that corresponds to the bacteria counts with February high (11.5 meq $CO_2 \times 10^{-4}$/g · hr) and a June low (1.9 meq $CO_2 \times 10^{-4}$/g · hr). Surface and subsurface samples were not significantly different. Dehydrogenase activity exhibited an opposite annual cycle to respiration. Dehydrogenase activity was highest in June (19 mg Forazan/L.) and lowest in February (8 mg Forazan/L.) during 1982. This cycle was quite different than that reported in 1981.

Correlations between chemical and microbiologic factors identified three major relationships:

(1) High bacterial counts and microbial respiration levels were associated with relatively moist soils.

(2) Bacterial numbers and activities tend to be positively correlated with organic-matter and negatively correlated with pH.

(3) Fungal counts were, in general, not correlated with any soil chemical characteristics.

The correlation coefficients are generally low (.2 - .5) for most analyses, but the relationships do represent logical patterns and will serve as valuable baseline information.

3.3 PROGRAM DESCRIPTION

3.3.1 Objectives

The three main objectives of the vegetation program are:

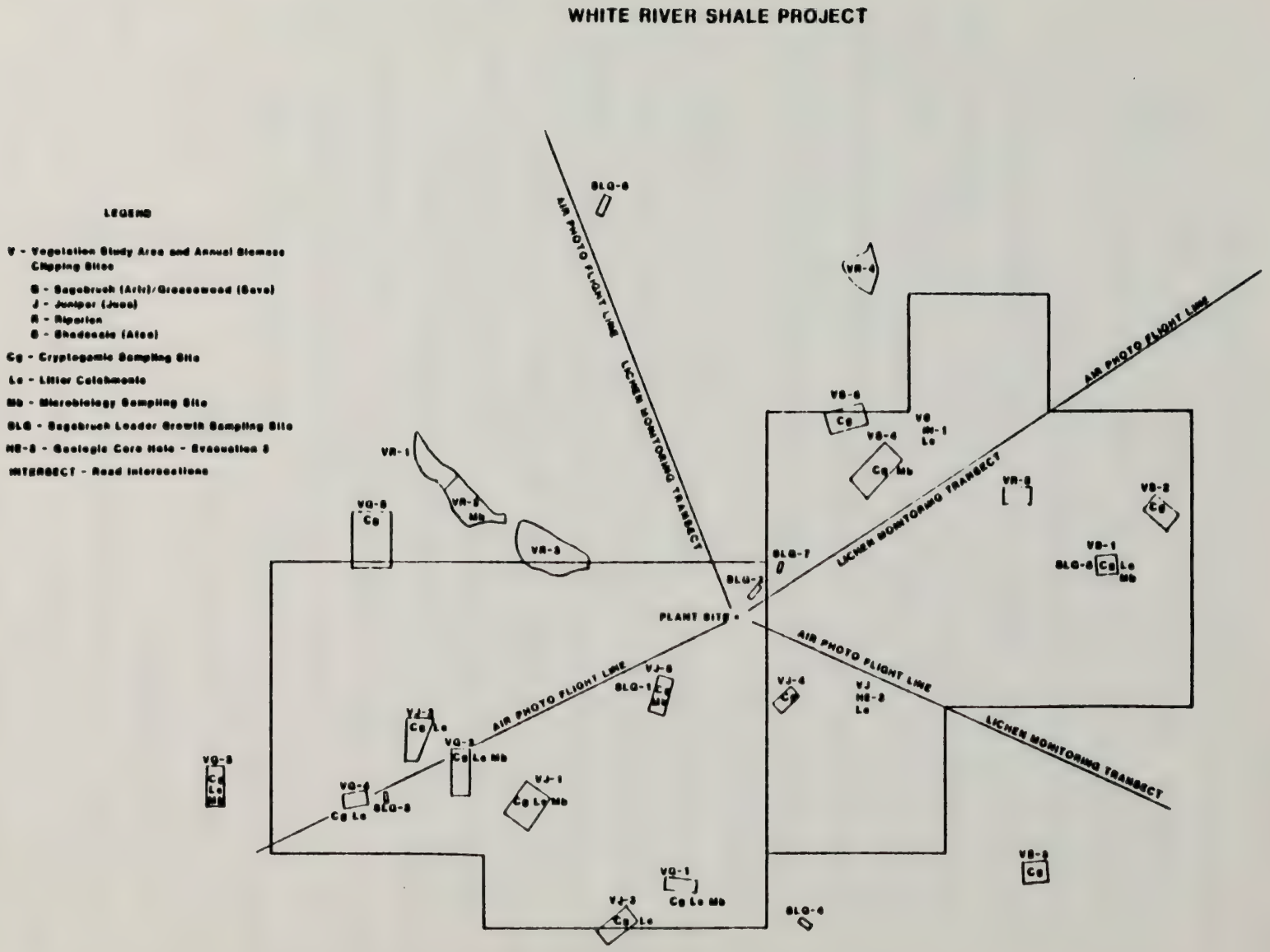
- To document the existing vegetation conditions during and after various stages of development, including the range of variation exhibited temporally and geographically.
- To quantify plant responses to environmental impacts created by development, thereby allowing comparisons of plant responses in areas of little or no impact with those in areas of relatively high impact.
- To measure the success of revegetation techniques on the processed shale disposal area and other areas that may be disturbed during operations.

In 1982, the first revegetation activities occurred. The disturbance was associated with construction of the new road to the plant site. Monitoring will be initiated beginning in 1983 for plant establishment and revegetation success. The area of greatest impact to the vegetation in terms of area disturbed, however, will be the processed shale pile. Revegetation techniques for processed shale are still being investigated and are discussed in Chapter 7. Many of the parameters discussed below will be used in monitoring the processed shale area, however, it is anticipated that other parameters may be identified from the special revegetation studies that could be added to the vegetation monitoring program at a later date.

3.3.2 Site Locations

The vegetation resources program continued to use the areas of sampling established in the 1974-76 baseline work and those areas initiated during 1981 by the addition of several new studies. The locations of all the study sites are shown in Figure 3.3-1. The actual overflights for detecting plant

Figure 3.3-1. Location of Vegetation Study Areas.



conditions and stress were extended so that the proposed processing plant represents the center of each transect and so the transects will better correspond to predicted effluent patterns. Details for the selection of the sites are discussed fully in the WRSOC Environmental Monitoring Manual (1982).

3.3.3 Methods

The methods used during the 1982 program are essentially the same as those utilized during the previous years of study. The WRSOC Environmental Monitoring Manual (EMM) contains a detailed description of the methods employed and the schedule for sampling. Deviations from the EMM occur primarily when sample sizes are adjusted to provide for more statistically valid data or when field conditions necessitate a change. Any such changes are described in the appropriate section of this report.

3.3.4 QA/QC Program

The Quality Assurance and Quality Control program described in the EMM was initiated during the 1982 program. The field and laboratory data collection has been verified and throughly documented. All pertinent data, both raw and summarized, have been placed onto computer tapes under the direction of WRSOC and according to the format specified. Duplicate tapes were made for the Oil Shale Office and for WRSOC files. Original data sheets are being kept in Native Plants, Inc. files.

Aerial photographic products were carefully monitored. Each frame has the altitude, time and date printed directly on them. Soils and chemical analysis have been done utilizing adequate replications to insure quality. Some errors have been identified during the course of this program and corrective actions have followed.

3.4 PROGRAM RESULTS AND ANALYSIS

Eight separate components are included in the vegetation monitoring program. Three of these are identified as operational parameters, Production of Annual Plant Biomass, Sagebrush Stem Growth and Soil Chemistry, and will probably be continuously monitored. Four components are listed as potential parameters including, Lichen Growth, Litterfall, Plant Conditions and Stress and Soil Microbiology. One final component is listed as a contingency parameter and that is Plant Chemical Composition. Along with this there are portions of the Soil Chemistry and Soil Microbiology parameters that will be included as contingency parameters. The results of each of these components are reported in the following sections.

3.4.1 Production of Annual Plant Biomass

In June, 1982, five productivity study areas were visited in each of the four major vegetation types identified during the baseline program (Refer to Figure 3.3-1 for the locations). In each study area, plant cover was recorded and aboveground annual plant biomass was harvested from twenty 0.25 m^2 plots. Plants were measured for height, clipped at ground level, and returned to the lab for weighing. Weights were recorded for each study site as well as cover percentages and these are shown in Tables 3.4-1-4.

Previous analysis have shown that annual species biomass is related to spring precipitation. Precipitation records for the water year 1981-82 show that the winter and spring months were generally above normal (Table 3.4-5). March had good precipitation (3.56 cm) and there was abundant soil moisture to initiate annual seed germination. April, however, had very little precipitation

Table 3.4-1. Biomass Production of Annual Vegetation. Vegetation Type: Shadscale (ATCO).

	Biomass Sites Weight (gm)					Biomass Sites Cover % (.25 m^2)				
Sample No.	1	2	3	4	5	1	2	3	4	5
1	1.9	18.2	9.3	9.6	1.6	3	15	7	6	2
2	3.5	2.4	3.1	13.5	4.2	2	3	3	12	4
3	2.6	3.8	18.7	8.2	15.6	2	1	14	6	20
4	1.0	9.9	26.0	2.8	6.0	1	7	50	3	10
5	3.8	9.9	11.9	2.1	9.2	2	5	9	4	7
6	2.7	9.4	1.1	0.7	2.6	1	12	1	1	2
7	2.1	16.1	0.7	3.5	5.9	3	15	1	3	10
8	0.7	25.3	28.6	2.0	7.6	1	10	45	2	4
9	2.1	0.5	0.7	8.0	10.1	1	1	1	15	7
10	8.4	7.9		0.3	1.1	5	4	0.5	1	1
11	2.2	11.2	13.1	0.4	0.9	2	15	16	1	1
12	1.5	0.2	0.8	8.8	2.1	3	0.5	1	17	2
13	1.6	1.1	19.3	4.9	5.1	1	1	16	5	5
14	4.0	6.2	0.9	9-8	6.3	2	8	1	12	4
15	1.5	2.8	0.4	0.4	1.0	1	2	1	1	1
16	2.1	6.3		0.1	6.4	2	5	0.2	1	7
17	2.0	4.4	36.0	18.1	0.2	1	3	60	30	1
18	3.3	0.7	0.3	17.5	8.9	3	1	1	15	7
19	4.9	3.4		0.1	7.8	4	2	0.5	0.6	7
20	7.7	9.5	9.2	3.2	11.6	4	5	5	4	7
$\overline{X}$	3.0	7.5	9.0	5.7	5.7	2.2	5.8	11.7	7.0	5.5
s.d.	2.0	6.6	11.2	5.7	4.1	1.2	5.1	18.2	7.6	4.5

Blank spaces indicate: weight less than 0.1 gm
cover less than 0.1%.

Table 3.4-2. Biomass Production of Annual Vegetation. Vegetation Type: Juniper (JUOS).

	Biomass Sites Weight (gm)					Biomass Sites Cover % (.25 m^2)				
Sample No.	1	2	3	4	5	1	2	3	4	5
1										
2								0.5		
3								0.3		
4			0.4			0.1		1		
5			1.5			0.1		3	0.5	
6	2.7			0.6		1.0		0.1	0.5	
7										
8				1.2		0.1	0.1		0.5	
9						0.1				
10								0.5	0.5	0.5
11									0.5	
12								0.9		
13						0.1		0.1	0.5	
14						0.5				0.1
15								0.1		0.1
16						0.1			0.5	0.1
17						0.5		0.3	0.5	
18										
19		0.1					0.5			
20		3.2					2	0.9		
$\overline{X}$	0.1	0.2	0.1	0.1	0.0	0.1	0.1	0.4	0.2	0.1
s.d.	0.6	0.7	0.3	0.3	0.0	0.3	0.5	0.7	0.3	0.1

Blank spaces indicate: weight less than 0.1 gm
cover less than 0.1%.

Table 3.4-3. Biomass Production of Annual Vegetation. Vegetation Type: Greasewood (SAVE).

	Biomass Sites Weight (gm)					Biomass Sites Cover % (.25 m^2)				
Sample No.	1	2	3	4	5	1	2	3	4	5
1		2.3	9.7	5.1		0.9	3	8	2	0.1
2	0.6		4.0	4.0	6.3	1	0.5	3	3	4
3	14.6	1.5	18.6	3.0	1.0	30	2	20	3	2
4	6.3	2.1	17.6		5.5	20	2	23	0.1	3
5	1.4	5.9	12.6		2.5	1	3	15	0.5	2
6	5.0	1.7	22.7		1.4	5	1	30		1
7	3.6		9.2		3.9	3	0.5	10		3
8	4.1	0.5	5.5	3.4	5.7	6	1	3	2	4
9		3.1	24.6	6.5	0.4	0.1	2	20	10	1
10	31.8	0.5	3.2	2.4	0.9	55	1	4	1	1
11	8.0	0.7	4.9	3.7	0.4	2	0.9	2	2	1
12		6.1	13.2	7.8	12.2		3	8	5	6
13	17.1		19.9	0.5	2.9	7	0.5	7	1	2
14	5.4		18.7	0.9	0.4	6	0.9	7	1	1
15	4.3	1.6		0.6	0.5	4	1	0.1	0.5	1
16	4.9		15.6		3.6	3		17		3
17		0.8	15.0		0.6		1	7		1
18		2.4				0.9	3	0.1	0.1	0.5
19	37.0	1.8	8.2	4.6	1.3	55	2	6	3	1
20	36.6	0.5	3.6	2.6	1.9	45	0.9	3	3	2
$\overline{X}$	9.0	1.6	11.3	2.3	2.6	12.2	1.5	9.7	1.9	2.0
s.d.	12.2	1.8	7.6	2.4	3.0	18.6	1.0	8.4	2.4	1.5

Blank spaces indicate: weight less than 0.1 gm
cover less than 0.1%.

Table 3.4-4. Biomass Production of Annual Vegetation. Vegetation Type: Riparian.

	Biomass Sites Weight (gm)					Biomass Sites Cover % (.25 m^2)				
Sample No.	1	2	3	4	5	1	2	3	4	5
1	9.2	93.4	94.1	3.7	12.3	6	55	85	4	25
2	1.8	54.5	29.3			2	70	20	0.1	0.5
3	10.0	40.0	15.4	0.5	5.2	6	60	15	1	6
4	0.8	30.9	32.5	12.4	3.5	1	55	27	8	3
5	1.8	17.3	12.3	5.7	8.7	3	15	10	4	6
6	9.8	52.1	17.9	1.7	1.9	5	55	16	1	2
7	13.7	19.0	33.3	1.0	3.7	5	15	55	1	4
8	11.5	28.6	45.2	1.0	8.0	7	35	40	1	6
9	25.7	19.2	35.4		6.9	15	7	55	0.1	4
10	14.8	2.8	44.9	0.6	4.9	6	2	35	1	3
11	24.6	5.1	38.0		10.3	25	4	45	0.1	6
12	16.8	19.8	26.7	7.2	7.5	10	10	25	4	6
13	20.6	37.7	19.5	5.8		25	55	30	3	
14	5.7		0.7			5	0.5	1		
15	16.9	0.9	28.5	6.6	5.1	30	1	60	3	6
16	33.1	18.3	28.9	5.7	0.2	45	8	55	4	0.6
17	14.4	33.5	64.7	5.0	4.0	17	35	65	3	4
18	20.6	31.8	52.6		10.1	30	30	55		8
19	11.7	20.6	38.8		4.0	30	23	55		3
20	8.6	46.3	25.8	22.5	2.3	5	42	60	15	2
$\bar{X}$	13.6	28.6	34.2	4.0	4.7	13.9	28.9	40.5	2.7	4.8
s.d.	8.4	22.2	20.2	5.5	3.9	12.6	23.2	21.9	3.6	5.3

Blank spaces indicate: weight less than 0.1 gm.
cover less than 0.1%.

Table 3.4.5 Monthly precipitation (cm) for the 1981-82 water year for the oil shale tracts Ua and Ub (data was provided by VTN).

Station	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
ARA-13	9.40	1.27	0.76	0.76	0.25	2.79	0.25	2.79	0.00	3.81	5.08	7.87	35.05
ARS-9	9.40	--	--	--	--	--	0.25	2.54	0.25	2.79	4.83	8.64	--
ARA-2	9.65	--	--	--	--	--	0.76	3.56	0.51	2.79	7.11	7.62	--
RS-11	8.64	1.57	0.69	1.09	Trace	3.68	Trace	3.90	0.28	3.12	4.65	8.74	35.36
RS-13	8.61	1.27	0.79	0.61	Trace	3.53	Trace	4.06	0.43	4.27	7.16	9.22	39.95
RA-4	9.40	1.42	1.65	0.79	Trace	3.96	Trace	2.18	0.25	3.12	1.78	8.20	32.77
RV-7	9.65	1.68	0.91	1.06	Trace	3.45	0.25	3.38	0.20	2.46	7.70	8.13	39.14
RV-8	9.65	1.37	0.81	1.09	Trace	3.68	Trace	3.20	0.23	3.68	4.78	8.43	36.93
RS-10	9.27	1.68	0.89	0.69	Trace	3.25	Trace	3.02	0.43	3.68	6.50	8.18	37.59
RB-1	8.51	1.40	1.35	1.09	Trace	4.09	Trace	3.10	0.23	4.47	4.39	8.56	37.19
Monthly $\bar{X}$	9.22	1.45	0.99	0.89	0.05	3.56	0.23	3.07	0.28	3.43	5.41	8.36	36.75

(.23 cm) and this caused the biomass yields to be lower than in 1975, 1978 or 1979. April is a critical period in the plant's growth and the poor rainfall caused a reduction in both plant height and biomass. The relationship between spring precipitation (April-June) that has been reported previously is weakened by the 1982 data. That regression relies primarily on the 1975 data point to provide strength to the relationship. A more accurate representation appears to be utilizing precipitation data from October through May and correlating this to annual biomass, since precipitation during this period serves as both the source for soil moisture recharge and available moisture during the germination and growth phases. Annual species biomass is harvested in the 1st week of June, so June precipitation data has no bearing on production and should be excluded from the analyses. A regression based on 1976-82 data for annual plant biomass and October-May precipitation shows a positive relationship which is statistically significant at α=.05 (Figure 3.4-1).

Comparisons of 1982 annual biomass data with the preceeding years are shown in Table 3.4-6. Biomass averages of all four vegetation types show that 1982 ranked fourth highest of the eight years of record in maximum biomass and was about 50% greater than biomass production in 1981. The upswing in rodent and rabbit populations took advantage of this additional and important source of herbage and seeds.

The riparian vegetation type again had the largest values for production and cover of the four vegetation types considered averaging 68.1 gm/m^2 and 18.2% respectively. The Juniper type had the lowest figures averaging 0.4 gm/m^2 for production and 0.2% for cover. Production values for individual

Figure 3.4-1. Regression Analysis of Precipitation and Annual Species Biomass. The regression is significant at $\alpha = .05$.

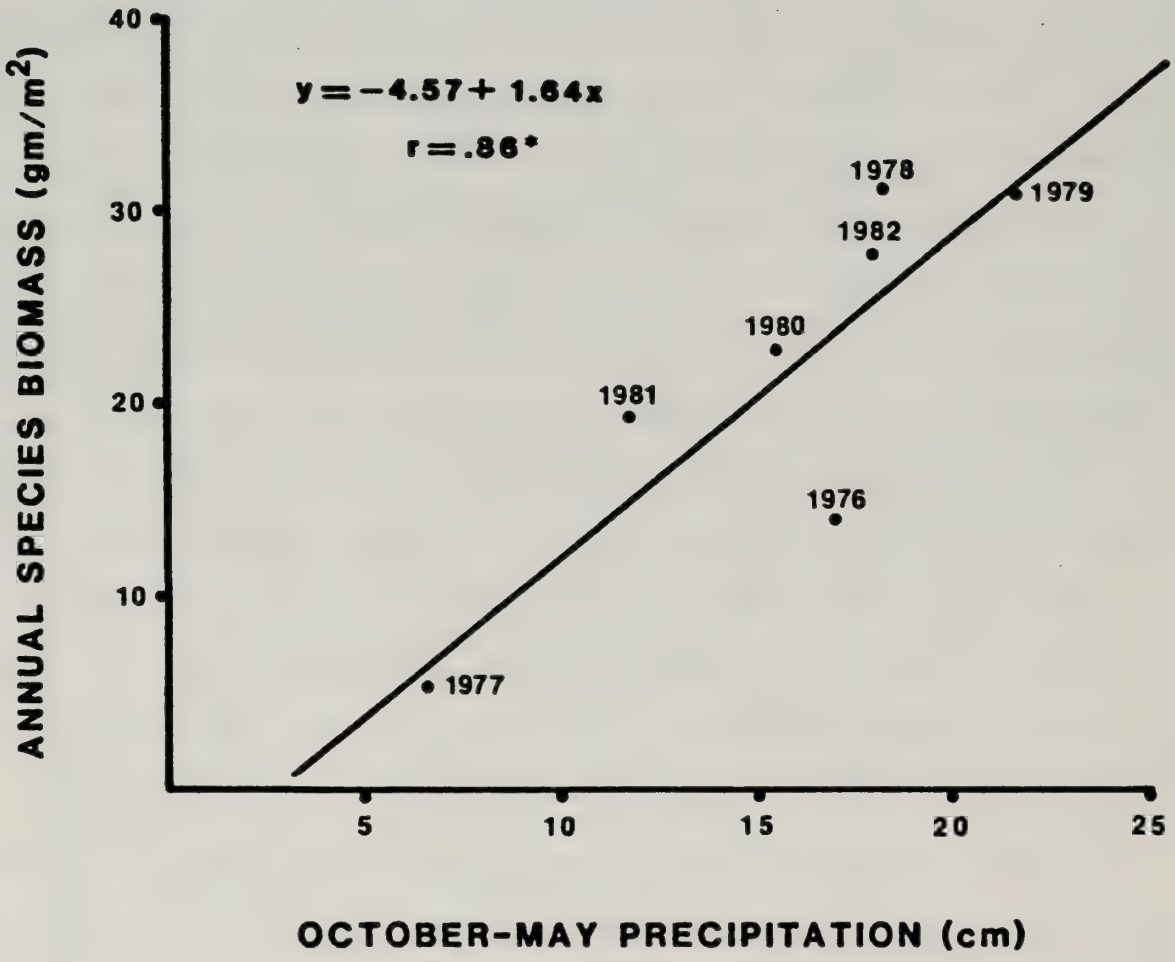


Table 3.4-6 Biomass production of annual understory vegetation of four primary vegetation types during 1982 and compared with previous years.

Sample Location (1)	VEGETATION TYPE: Shadscale Production (gm/m^2)	Shadscale Plant Cover (%)	Sagebrush-Greasewood Production (gm/m^2)	Sagebrush-Greasewood Plant Cover (%)	Juniper Production (gm/m^2)	Juniper Plant Cover (%)	Riparian Production (gm/m^2)	Riparian Plant Cover (%)
1	12.0	2.2	36.0	12.2	.4	.1	54.4	13.9
2	30.0	5.8	6.4	1.5	.8	.1	114.4	28.9
3	36.0	11.7	45.2	9.7	.4	.4	136.8	40.5
4	22.8	7.0	9.2	1.9	.4	.2	16	2.7
5	22.8	5.5	10.4	2.0	0	.1	18.8	4.8
1982 Avg.	24.7	6.4	21.4	5.5	0.4	0.2	68.1	18.2
1981 Avg.	9.2	3.4	15.8	4.8	0.6	0.2	51.5	17.4
1980 Avg.	21.8	2.3	8.9	0.9	0.5	trace	(3)	(3)
1979 Avg.	16.5		16.9		6.3		82.5	
1978 Avg.	5.4		35.1		1.6		80.0	
1977 Avg.	0.0(2)		0.0(2)		0.0(2)		20.6	
1976 Avg.	3.8		20.9		0.3		30.6	
1975 Avg.	224.3		51.1		3.8		590.0	

(1) Each value is a mean of 20 plots within areas sampled during and since the Baseline.

(2) Vegetation was not sampled (too meager to harvest).

(3) Biomass sampling data unavailable because of sample handling problem.

vegetation types are discussed below.

3.4.1.1 Shadscale Vegetation Type Annual species biomass was the second highest ($\bar{x}$ = 24.7 gm/m^2) of the eight years of record for this vegetation type in 1982. Cheatgrass was again the dominant annual species on this vegetation type and it occurred most frequently in protected areas underneath shrubs. Cover estimates averaged 6.4% with a range from 2% to 11.7%.

3.4.1.2 Sagebrush - Greasewood Vegetation Type Annual species production in the sagebrush - greasewood areas averaged 21.4 gm/m^2. This total is the third highest biomass yields to date, yet it is still low in comparison to 1975 or 1978 production values. The general pattern of plant distribution was similar to the shadscale type with most of the production occurring underneath the shrubs and open areas between shrubs being essentially bare of annual plants. Besides cheatgrass, an annual *Cryptantha* sp. and pepperweed (*Lepidium perfoliatum*) were occasionally found within this vegetation type. Cover values for the annual species were similar to 1981 values with an average cover value of 5.5% and a range of 1.5% to 12.2%

3.4.1.3 Juniper Vegetation Type The production of annual species in this vegetation type was very low as is typical with the juniper zone. Average production was only 0.4 gm/m^2 compared with 0.5 gm/m^2 in 1981. The dominant annual speices in this type was cheatgrass with some lambs' quarters (*Chenopdium album*) and pepperweed. The total cover in the juniper sites samples averaged 0.2% cover which is identical to 1981 data.

3.4.1.4 Riparian Vegetation Type As in all previous years, the riparian vegetation type produced the most annual plant biomass. Again, the domi-

nant annual species was cheatgrass, with a fair abundance of yellow sweet-clover (Melilotus officinalis), pepperweed, and fat hen saltbush (Atriplex patula). The grazing pressure on the riparian areas is more severe than on the other vegetation types and much of this disturbance leads to an increase in the preponderance of annuals. These annuals may in turn serve as a source of food for animals during a short period in the spring. The production of annuals for 1982 averaged 68.1 gm/m^2. Average cover values for the riparian vegetation sites ranged from 3% to 41% with an average cover of 18%.

3.4.2 Sagebrush Leader Growth

There was no change in methodology used for sampling sagebrush stem growth measurements during 1982. The annual growth of 20 stems on each of 20 separate plants in each of seven sampling locations (2800 samples total) was measured. Locations of the sampling sites are shown in Figure 3.3-1. Each measurement was from the bud-scale scar of the previous year to the tip of the new growth. This marks the eighth year that this data has been collected on SLG-1-6 and the second year of data for SLG-7. Results of each site for 1982 are shown in Tables 3.4-7-13.

Growing conditions for sagebrush in 1982 should have been very good for stem growth, but this is not generally reflected in the stem lengths. The variability of stem length is apparently highly correlated with fall-winter precipitation (Figure 3.4-2). The precipitation for the fall-winter period for 1982 averaged 15.2 cm which was the second highest average recorded. Stem length was considerably below the value that would be predicted strictly by the regression equation but it was still within the 95% prediction interval

Table 3.4-7. Sagebrush stem length (cm) as measured in October 1982. Site 1 .

SAGEBRUSH STEM LENGTH (CM)

SHRUB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	$\bar{X}$ (cm)	SD
1	5.6	5.1	7.2	7.3	7.6	5.6	10.3	5.0	5.6	4.0	6.8	3.7	3.6	7.6	3.0	5.3	3.4	5.0	6.5	7.6	5.8	1.8
2	5.2	5.7	2.7	3.3	4.1	1.7	3.2	3.2	2.3	4.5	5.0	7.1	6.8	1.5	3.4	5.1	3.5	5.7	5.8	9.1	4.4	1.9
3	1.6	5.9	4.3	9.5	3.5	4.6	3.1	3.5	3.0	5.9	2.4	5.5	7.6	9.2	5.4	3.9	3.8	6.1	7.5	7.4	5.2	2.2
4	1.6	1.5	5.3	0.9	2.6	3.4	3.8	2.3	5.0	2.2	1.9	2.6	1.5	2.6	1.6	4.9	2.3	2.3	4.2	2.8	2.8	1.3
5	4.1	3.1	4.9	3.5	2.9	6.1	3.6	4.8	1.1	3.1	1.6	3.4	3.0	3.5	3.8	2.4	7.4	3.7	4.5	4.3	3.7	1.5
6	5.0	5.1	4.0	3.1	3.4	6.6	6.6	4.0	4.3	8.0	5.6	4.2	4.3	6.5	3.7	8.2	6.6	5.4	2.8	5.1	5.1	1.6
7	5.7	6.2	3.1	3.1	4.1	3.9	6.5	3.7	4.6	5.7	4.1	4.4	3.5	4.0	2.7	4.7	6.2	5.7	4.0	3.6	4.5	1.1
8	4.1	5.3	4.1	3.2	1.7	4.2	5.2	3.0	5.2	5.1	3.0	3.0	7.2	3.1	6.0	4.7	5.7	7.9	2.1	5.1	4.4	1.6
9	3.6	3.7	3.0	4.2	3.9	8.7	2.7	3.9	4.5	3.7	2.6	3.6	6.4	3.5	3.6	5.1	4.5	3.7	1.4	3.2	4.0	1.5
10	3.8	2.9	3.1	3.0	5.6	2.1	2.1	3.0	2.3	3.0	3.5	4.0	2.1	2.8	2.6	2.9	3.0	3.1	3.3	2.6	3.0	0.8
11	6.8	6.0	6.4	6.4	7.4	7.7	7.5	10.6	9.5	8.3	9.2	4.5	10.6	8.0	9.4	5.8	8.5	6.2	7.3	7.1	7.7	1.6
12	4.9	6.9	4.7	5.7	6.6	4.0	4.0	5.2	3.4	5.5	5.0	5.4	4.2	5.5	5.1	4.9	4.6	3.8	3.1	3.2	4.8	1.0
13	3.3	6.1	2.3	2.3	2.1	3.4	3.0	4.7	4.4	3.6	2.7	1.8	4.2	4.8	2.9	2.4	4.1	2.2	3.1	2.8	3.3	1.1
14	1.8	7.5	3.5	4.7	1.3	6.3	2.0	3.5	4.1	2.9	2.5	2.9	6.0	3.7	6.5	4.2	3.5	5.2	8.2	2.6	4.1	1.9
15	7.3	5.8	4.5	4.6	3.0	5.2	4.6	5.0	5.6	6.1	3.5	5.1	7.5	5.6	6.4	4.5	6.4	7.4	3.7	4.4	5.3	0.9
16	8.2	4.0	4.7	6.3	4.4	7.4	5.4	5.5	7.4	8.6	3.2	4.6	3.5	6.6	3.0	3.5	5.5	4.7	4.0	4.9	5.3	1.7
17	5.0	2.7	2.4	4.5	6.6	3.7	5.0	8.7	2.0	7.1	2.3	5.2	2.1	3.3	3.7	4.0	7.4	4.2	4.3	4.3	4.4	1.9
18	2.0	1.6	1.7	1.9	1.3	3.2	1.1	1.5	1.5	1.4	2.4	2.0	1.4	3.7	1.7	1.2	1.2	1.4	2.0	1.6	1.8	0.7
19	7.6	4.6	4.5	3.5	4.1	4.7	7.2	4.2	6.1	4.6	5.1	2.1	3.0	4.0	3.5	8.7	4.2	4.7	1.9	2.0	4.5	1.8
20	5.7	3.2	5.1	7.0	8.5	3.7	6.5	7.2	5.4	5.0	4.0	4.9	3.3	3.6	4.9	2.6	2.3	5.7	5.2	3.3	4.9	1.6

Site Location: $\bar{X}$ - 4.5 cm
SD - 1.2

Table 3.4-8. Sagebrush stem length (cm) as measured in October 1982. Site 2 .

SAGEBRUSH STEM LENGTH (CM)

SHRUB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	$\bar{X}$ (cm)	SD
1	3.2	2.4	3.3	6.4	3.6	6.8	9.9	7.6	7.5	6.3	2.6	1.7	4.3	4.8	3.6	3.8	7.1	5.5	4.4	8.5	5.2	2.2
2	6.1	3.0	4.9	5.2	7.8	5.6	6.3	9.3	3.9	7.4	7.8	7.2	4.3	4.0	3.4	7.6	6.2	6.6	3.7	4.7	5.8	1.8
3	4.8	6.3	7.5	9.0	7.1	5.9	2.3	7.7	10.9	8.0	4.6	3.5	5.4	6.3	3.5	7.4	6.4	5.9	3.6	1.4	5.9	2.3
4	2.9	2.8	8.2	8.4	7.3	5.5	8.4	5.2	7.6	7.4	5.0	5.0	5.1	5.8	5.4	3.9	8.4	6.6	4.1	8.3	6.1	1.9
5	10.3	10.8	8.8	9.1	9.0	6.3	4.2	7-7	7.1	9.4	7.7	8.4	4.8	8.6	6.9	7.8	6.5	12.6	8.7	3.1	7.9	2.3
6	6.4	8.2	4.3	6.7	5.1	4.9	3.8	5.1	6.0	1.8	5.1	7.0	6.9	5.2	5.4	6.2	4.8	7.6	1.2	3.4	5.3	1.8
7	1.5	4.6	5.1	4.7	2.6	0.8	3.6	4.8	3.6	2.0	2.2	0.5	0.6	6.1	4.6	4.2	1.5	4.1	3.7	3.2	3.2	1.6
8	2.8	2.6	2.0	2.7	1.5	1.3	4.5	3.6	2.1	2.2	4.3	1.8	5.8	2.6	1.4	1.4	2.5	1.6	2.0	1.4	2.5	1.2
9	9.6	11.5	7.8	9.9	11.8	8.4	5.5	7.0	8.6	7.0	9.4	6.4	7.5	6.7	7.1	5.8	7.4	6.6	8.6	6.9	8.0	1.7
10	3.5	3.7	3.2	4.3	5.5	5.8	2.5	4.5	1.2	3.6	2.7	2.8	2.8	3.2	3.7	4.3	6.4	3.8	4.3	8.0	4.0	1.5
11	3.6	3.6	3.9	4.9	2.1	2.1	2.3	3.6	3.1	1.0	2.1	1.8	3.4	1.9	3.2	3.0	3.8	4.1	2.2	1.8	2.9	1.0
12	4.4	4.5	5.5	5.2	2.7	3.7	7.1	5.2	5.0	8.5	2.5	5.1	3.8	5.1	3.9	4.0	4.9	3.4	6.0	8.6	5.0	1.6
13	7.2	6.8	7.0	6.4	10.5	10.8	7.4	4.7	3.8	7.1	5.6	7.6	5.3	7.5	4.8	5.4	6.9	5.0	4.1	6.0	6.5	1.8
14	1.7	1.5	1.2	2.1	1.9	3.8	2.4	1.7	2.5	1.0	2.2	3.3	1.2	1.7	1.6	0.7	1.1	1.5	1.8	1.2	1.8	0.8
15	5.0	5.7	10.0	9.4	12.4	11.1	8.2	9.7	9.4	8.6	8.4	4.3	4.6	6.0	4.7	4.9	5.8	8.2	6.6	4.5	7.4	2.5
16	4.2	2.3	3.4	4.1	4.6	4.6	3.9	6.5	4.4	7.4	4.5	6.7	7.2	4.3	2.4	5.0	6.8	3.0	3.8	5.9	4.8	1.5
17	4.4	2.8	4.1	3.5	4.4	6.7	3.8	5.1	5.2	3.2	4.1	3.9	3.2	3.9	4.5	4.0	2.4	5.5	4.7	3.8	4.2	1.0
18	6.7	6.9	5.5	3.6	4.2	7.3	3.6	5.9	3.8	3.2	5.5	6.7	2.9	5.5	2.8	3.3	6.0	3.4	4.2	6.1	4.9	1.5
19	6.3	4.4	5.0	3.6	4.5	5.1	5.9	1.8	6.6	5.8	4.3	3.2	5.2	4.6	5.6	4.4	2.7	5.4	6.7	7.0	4.9	1.4
20	2.5	6.0	2.2	2.0	2.2	3.4	3.5	2.3	2.0	1.1	2.3	2.9	1.4	1.0	0.8	1.5	1.9	1.7	3.0	0.7	2.2	1.2

Site Location: $\bar{X}$ - 5.2 cm

SD - 1.4

Table 3.4-9. Sagebrush stem length (cm) as measured in October 1982. Site 3 .

SAGEBRUSH STEM LENGTH (CM)

SHRUB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	$\bar{X}$ (cm)	SD
1	7.5	9.2	8.2	6.6	7.8	5.7	9.6	9.0	3.8	6.9	8.2	5.4	8.2	9.0	5.3	4.6	6.0	6.4	4.8	4.9	6.9	1.8
2	3.5	7.8	4.3	7.0	7.2	4.7	3.2	1.8	6.2	8.0	9.5	3.3	7.5	6.3	3.3	6.2	7.2	6.4	10.0	5.4	5.9	2.2
3	4.1	5.3	7.3	5.6	8.1	4.2	4.8	4.1	6.2	6.5	4.0	6.7	5.4	6.9	4.3	7.7	4.0	5.8	5.9	3.3	5.5	1.4
4	5.9	5.3	6.4	6.5	4.7	6.6	4.5	8.0	5.6	6.2	6.3	6.9	6.3	6.8	5.9	6.9	6.6	7.0	8.0	7.1	6.4	0.9
5	2.0	2.7	8.2	10.9	9.2	8.7	50.0	1.6	8.3	5.1	3.7	3.5	6.3	7.4	5.5	6.1	4.3	8.2	5.0	4.8	5.8	2.5
6	10.8	9.6	7.5	6.0	8.2	10.4	6.6	7.3	7.1	8.6	8.7	8.7	5.5	10.6	9.0	4.6	6.8	7.0	7.3	5.0	7.8	1.8
7	7.6	7.7	6.2	5.1	4.6	5.6	6.8	6.5	3.6	7.2	6.5	4-7	6.3	6.0	6.4	3.4	4.5	3.6	7.0	3.5	5.6	1.4
8	10.9	5.5	4.8	4.8	5.9	9.2	8.1	9.0	7.6	8.6	8.2	8.9	10.2	8.1	5.1	6.2	6.6	5.1	4.2	7.6	7.2	2.0
9	8.4	10.0	7.2	8.0	7.8	6.8	8.4	10.0	4.2	8.0	6.0	6.3	6.7	8.0	7.1	9.0	5.4	7.0	7.5	3.8	7.3	1.6
10	4.2	3.7	3.8	3.5	5.2	3.7	4.9	3.5	3.7	5.0	3.2	7.6	6.2	3.6	4.8	4.4	4.4	3.0	3.9	4.5	4.3	1.1
11	3.7	9.8	8.2	9.2	3.7	5.1	6.2	6.1	8.4	7.9	6.1	3.2	4.4	6.5	7.3	8.6	3.9	5.5	4.7	3.5	6.1	2.1
12	4.5	8.0	8.5	5.0	5.1	9.0	8.5	4.2	6.2	6.0	4.6	5.8	6.2	6.3	8.2	5.4	5.3	4.5	5.0	3.9	6.0	1.6
13	4.9	6.3	3.6	1.1	5.0	3.7	3.7	1.6	3.2	5.0	4.5	4.7	2.8	4.2	1.6	4.3	3.2	2.9	2.8	4.2	3.7	1.3
14	6.4	5.6	4.2	6.3	8.6	7.7	10.5	8.6	5.1	6.4	4.8	4.9	8.2	6.2	8.6	9.9	9.6	5.6	8.6	5.3	7.1	1.9
15	2.3	6.3	7.7	5.4	6.8	5.3	8.0	6.2	6.8	4.8	5.5	3.9	6.7	3.2	2.7	5.6	9.2	9.8	5.5	6.8	5.9	2.0
16	6.3	3.6	4.8	5.9	6.2	4.7	6.2	8.2	4.1	8.3	3.1	4.5	5.0	5.0	4.3	5.0	7.5	4.6	4.8	3.2	5.3	1.5
17	5.1	2.0	4.3	4.4	6.9	4.4	3.2	5.8	6.0	3.7	4.2	5.7	5.2	3.1	6.3	5.2	3.8	4.2	2.8	5.5	4.6	1.3
18	3.8	6.0	4.6	4.6	5.9	3.6	3.5	4.1	1.7	4.0	4.7	2.3	4.7	3.8	4.4	3.0	3.0	4.6	5.7	3.6	4.1	1.1
19	6.9	7.0	7.6	5.5	9.3	5.6	5.9	4.6	9.5	5.5	7.2	9.4	4.8	6.0	8.7	7.4	9.3	7.6	5.3	5.9	7.0	1.6
20	5.7	5.9	4.2	4.5	8.5	10.2	6.7	10.7	4.3	5.1	6.8	4.2	5.4	2.3	7.7	8.0	6.0	5.6	9.2	6.2	6.4	2.2

Site Location: $\bar{X}$ - 5.9 cm

SD - 1.1

Table 3.4-10 Sagebrush stem length (cm) as measured in October 1982. Site 4 .

SAGEBRUSH STEM LENGTH (CM)

SHRUB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	$\bar{X}$ (cm)	SD
1	6.5	5.0	5.5	5.5	6.5	6.0	7.0	6.0	4.5	8.0	7.0	5.0	5.5	6.5	7.0	8.0	6.5	4.0	5.0	6.5	6.1	1.1
2	2.5	3.5	3.5	1.5	2.5	3.0	2.0	3.0	3.5	3.5	5.0	4.0	3.0	3.5	5.0	2.0	3.5	1.5	3.0	2.5	3.1	1.0
3	5.0	5.5	4.0	6.0	4.0	6.5	4.5	6.0	3.0	9.5	5.0	6.5	7.0	3.0	4.0	6.0	5.5	3.5	9.5	4.5	5.4	1.8
4	7.0	8.5	4.0	7.5	3.5	5.0	7.0	1.0	5.0	7.0	5.0	8.5	8.0	3.0	6.5	3.5	8.0	3.5	8.0	8.0	5.9	2.2
5	8.0	6.0	4.0	10.0	7.0	9.5	8.0	12.0	6.5	6.0	6.0	7.5	6.0	6.0	7.5	6.0	7.0	5.0	8.0	8.0	7.2	1.8
6	6.0	5.0	7.0	4.0	6.0	7.0	4.0	3.0	5.0	7.5	6.0	6.0	8.0	6.0	5.0	3.0	4.0	3.0	6.0	4.5	5.3	1.5
7	6.0	4.0	4.0	4.0	5.0	4.5	6.0	7.5	4.0	3.0	5.0	3.0	4.0	6.5	4.5	4.0	4.5	4.0	7.5	3.5	4.7	1.3
8	7.0	8.0	3.5	3.0	6.5	3.5	6.0	3.5	5.0	5.0	6.0	4.0	4.5	3.5	6.0	2.5	3.5	3.0	2.5	3.5	4.5	1.6
9	4.0	5.0	3.5	5.5	3.5	3.5	4.5	5.5	4.5	6.0	2.0	4.0	4.0	5.0	5.0	3.0	4.0	3.5	4.0	4.5	4.2	1.0
10	8.0	8.0	5.5	5.0	6.0	5.0	5.0	6.0	5.5	6.5	7.0	2.5	5.0	4.0	4.5	6.5	5.5	4.0	5.0	5.0	5.5	1.3
11	6.0	4.5	3.5	4.0	5.0	5.0	7.5	4.5	6.0	4.0	9.0	5.0	9.5	6.5	6.0	8.0	5.5	3.0	10.0	4.5	5.9	2.0
12	5.5	8.0	9.0	7.5	5.5	2.0	7.0	6.0	4.0	5.0	4.0	5.0	4.5	1.5	7.0	8.5	3.0	5.5	6.5	3.5	5.4	2.1
13	4.0	6.0	4.0	8.5	4.5	5.0	5.0	3.0	6.0	9.0	5.5	5.0	5.0	4.5	6.0	5.0	4.5	4.0	7.0	8.0	5.5	1.6
14	2.5	2.5	4.0	2.0	1.5	5.0	2.5	6.5	2.5	3.5	3.0	2.5	3.5	3.5	6.0	2.0	2.5	1.5	2.5	4.0	3.2	1.4
15	2.0	4.0	6.0	3.0	3.0	3.5	5.0	3.5	5.5	4.5	3.5	3.0	4.0	4.5	3.5	2.5	4.0	4.5	3.0	4.0	3.8	1.0
16	4.5	2.0	2.0	2.0	2.5	2.5	6.0	1.5	3.5	3.5	1.5	6.0	3.0	2.5	3.5	1.5	3.0	3.0	2.0	4.0	2.9	1.3
17	3.0	2.5	5.0	3.0	9.0	4.0	4.5	4.5	6.5	8.0	10.0	3.0	1.5	3.5	2.0	2.5	3.5	7.5	7.0	4.5	4.8	2.4
18	3.5	5.5	3.0	1.5	3.5	5.5	4.0	4.5	3.5	1.5	2.0	4.0	3.0	4.5	3.5	4.0	4.0	4.0	3.5	3.5	3.6	1.1
19	5.5	5.0	4.0	4.0	2.5	4.0	5.5	5.0	4.5	4.0	5.0	5.0	3.0	4.5	5.0	6.0	2.5	6.0	4.5	5.0	4.5	1.0
20	7.0	4.5	5.5	5.0	4.0	7.0	6.0	4.5	7.0	6.0	6.0	4.5	4.0	5.5	4.5	3.0	6.0	7.5	5.0	4.0	5.3	1.2

Site Location: $\bar{X}$ - 4.8 cm
SD - 1.1

Table 3.4-11. Sagebrush stem length (cm) as measured in October 1982. Site 5 .

SAGEBRUSH STEM LENGTH (CM)

SHRUB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	$\bar{X}$ (cm)	SD
1	3.2	5.1	3.1	5.0	5.5	4.2	3.3	2.4	3.4	4.6	4.2	1.6	3.2	2.4	3.6	4.3	3.2	2.6	5.0	3.1	3.7	1.
2	2.9	4.5	1.3	4.0	4.1	3.6	2.8	2.7	1.4	4.0	4.2	4.6	7.6	2.2	4.5	4.1	4.2	2.2	4.5	4.1	3.7	1.
3	3.3	3.5	4.1	3.3	2.0	2.0	2.2	3.5	4.0	4.1	3.1	3.7	2.5	3.4	5.3	5.5	4.8	4.0	5.0	3.1	3.6	1.
4	2.7	2.8	3.2	2.4	3.2	3.6	3.6	1.6	2.5	2.2	3.1	3.6	2.0	3.1	3.2	2.6	3.1	1.9	2.7	3.5	2.8	0.
5	7.0	4.0	2.3	3.4	1.7	2.8	2.4	2.5	2.8	4.5	2.9	3.6	3.7	1.3	4.1	4.9	4.8	5.5	2.0	3.4	3.5	1.
6	1.8	3.0	1.9	3.8	2.8	3.5	3.7	2.3	3.6	3.0	6.0	1.7	2.9	2.8	1.7	2.8	4.3	1.8	2.5	3.7	3.0	1.
7	4.9	4.2	1.5	2.3	1.9	3.2	3.1	4.0	1.2	2.3	5.0	4.4	3.4	4.5	1.6	1.5	1.0	2.1	2.7	1.2	2.8	1.
8	3.1	2.6	3.5	2.8	4.0	2.5	3.2	4.3	2.2	2.6	1.5	2.7	6.0	1.9	1.8	4.0	2.2	2.6	1.2	1.5	2.9	1.
9	1.7	3.2	3.2	1.2	3.4	5.3	3.2	2.8	5.5	4.8	2.2	1.7	1.8	2.3	2.0	3.6	2.7	4.0	3.0	3.2	3.0	1.
10	5.9	4.5	4.7	2.7	4.8	4.8	1.2	2.0	3.6	5.6	4.2	4.5	3.4	3.5	4.1	6.2	3.0	1.8	1.7	2.3	3.8	1.
11	1.7	2.8	2.9	3.1	4.0	1.7	1.5	1.2	3.3	3.0	3.3	2.0	1.8	4.0	1.7	1.9	1.8	2.3	1.5	1.7	2.4	0.
12	3.5	2.8	3.5	3.9	5.2	2.5	2.8	2.5	2.6	2.5	3.7	2.8	3.4	3.5	3.5	4.0	4.4	4.8	2.2	2.7	3.3	0.
13	1.2	1.5	1.0	1.2	4.3	1.8	6.2	1.0	1.4	1.5	3.2	1.4	2.4	1.8	1.0	1.0	1.2	1.6	1.3	1.3	1.9	1.
14	2.6	1.1	3.6	1.6	3.0	3.9	2.6	1.6	1.8	1.0	2.9	1.3	1.9	1.2	5.3	4.1	2.6	4.0	4.0	4.1	2.7	1.
15	2.5	1.3	5.5	2.6	1.8	2.3	2.5	1.5	2.3	1.4	5.0	2.7	2.1	3.5	3.6	3.3	2.2	2.1	3.6	4.4	2.8	1.
16	3.7	3.1	1.7	1.7	1.2	5.6	7.3	6.8	3.0	2.4	3.8	4.3	4.0	5.1	1.7	3.0	3.4	5.3	2.0	3.7	3.6	1.
17	0.7	2.3	1.4	3.8	2.7	1.5	2.3	1.3	1.3	1.3	2.9	1.4	0.9	1.2	1.3	1.5	2.6	1.1	1.0	1.2	1.7	0.
18	2.5	2.7	2.0	4.6	2.6	2.7	3.5	3.6	1.8	3.7	3.0	2.7	4.0	2.7	1.7	4.7	2.3	5.1	5.6	2.5	3.2	1.
19	4.0	3.5	3.8	3.5	2.2	2.7	2.1	1.5	2.1	1.5	1.1	2.9	3.4	3.7	3.2	3.3	5.5	1.8	3.3	1.8	2.8	1.
20	5.3	2.6	1.9	1.4	3.1	3.6	3.8	2.4	2.1	2.6	4.8	3.6	3.8	1.2	2.7	4.8	3.2	3.5	3.0	2.6	3.1	1.

Site Location: $\bar{X}$ - 3.0 cm
SD - 0.6

Table 3.4-12 Sagebrush stem length (cm) as measured in October 1982. Site 6.

SHRUB	SAGEBRUSH STEM LENGTH (CM) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	$\bar{X}$ (cm)	SD
1	4.3	4.0	3.7	4.0	3.8	3.5	3.4	2.9	3.6	3.7	3.3	3.5	3.0	4.0	3.1	3.0	3.5	5.2	4.6	2.9	3.7	0.6
2	4.8	4.5	2.7	7.3	3.5	5.6	7.6	4.2	6.6	5.6	3.8	4.2	4.3	5.5	3.7	4.1	3.2	6.2	4.2	2.3	4.7	1.4
3	3.4	1.8	5.6	7.6	5.4	3.3	5.1	2.8	4.5	2.9	4.7	2.5	1.0	4.4	4.4	2.7	2.1	6.2	3.7	3.2	3.9	1.6
4	2.6	2.4	1.6	2.0	1.9	2.9	4.8	4.2	1.8	3.2	2.6	2.5	5.1	2.7	2.0	3.8	3.0	2.2	2.2	2.4	2.8	1.0
5	4.9	5.3	8.7	4.6	6.2	7.8	7.3	5.9	6.2	7.4	6.1	6.4	4.8	6.0	4.8	4.2	2.9	3.6	5.6	1.5	5.5	1.7
6	3.6	6.5	2.4	4.0	1.4	4.9	4.8	8.3	2.4	3.0	3.2	2.4	3.1	4.6	5.5	5.5	2.3	2.0	2.1	4.6	3.8	1.8
7	5.9	2.6	3.9	3.2	2.6	3.5	3.2	5.5	5.6	3.2	4.3	3.3	2.7	1.7	2.6	2.6	4.7	4.6	5.9	3.8	3.8	1.2
8	3.0	8.3	5.6	3.5	9.5	9.7	4.0	4.1	7.0	11.1	2.6	7.9	7.0	7.0	8.3	7.1	2.6	1.6	3.7	7.2	6.0	2.7
9	2.8	6.2	3.6	8.2	9.5	11.4	6.5	10.5	1.7	7.5	11.2	1.8	4.4	9.9	10.5	10.3	8.3	2.3	0.8	3.2	6.5	3.7
10	4.6	4.4	3.2	3.0	5.8	3.2	4.5	6.7	3.9	2.6	3.4	2.9	5.9	3.6	4.9	4.4	4.0	2.9	3.5	3.4	4.0	1.1
11	6.3	5.1	3.2	5.5	4.7	2.8	6.5	4.9	3.9	4.0	3.1	3.5	3.6	6.7	4.3	3.2	3.9	3.6	4.3	2.8	4.3	1.2
12	5.1	6.6	2.0	6.7	7.0	4.3	4.0	2.9	2.0	4.1	4.4	4.0	1.9	5.4	2.5	4.5	5.2	3.0	4.0	3.7	4.2	1.5
13	5.1	5.3	2.0	5.4	6.1	3.2	4.1	3.0	2.0	3.3	5.0	3.7	4.0	3.7	3.2	1.2	6.0	3.4	4.0	2.0	3.8	1.4
14	6.8	5.2	8.9	5.3	7.9	9.2	5.5	6.6	3.4	6.2	3.4	3.9	5.6	8.7	8.8	8.7	6.0	6.2	8.4	7.6	6.6	1.9
15	3.6	2.0	2.0	1.7	2.4	2.0	2.3	4.5	1.5	1.9	3.2	1.9	4.7	3.0	2.2	4.0	4.2	2.0	2.0	5.7	2.8	1.2
16	7.5	10.0	7.6	5.0	7.6	6.6	6.9	9.2	8.4	8.6	3.9	6.7	6.5	11.0	9.0	10.5	2.9	10.7	8.9	12.0	8.0	2.4
17	4.6	5.7	3.9	3.5	4.7	2.8	5.1	4.7	4.2	6.2	2.2	1.2	4.5	4.3	4.3	3.0	3.4	2.1	5.7	5.1	4.1	1.3
18	5.5	4.0	3.5	5.0	4.8	4.9	3.0	2.6	3.6	5.8	3.7	3.8	4.2	2.1	4.2	4.5	3.8	3.8	3.7	4.2	4.0	0.9
19	4.2	7.5	5.2	8.2	4.7	8.8	3.2	2.8	10.1	3.8	3.0	5.7	5.9	2.3	2.0	5.8	3.2	6.2	5.4	8.2	5.3	2.3
20	10.6	8.0	6.8	4.3	6.9	5.1	7.9	10.0	12.4	5.4	11.1	4.8	11.5	8.6	10.2	5.6	5.0	10.3	11.8	5.6	8.1	2.7

Site Location: $\bar{X}$ - 4.8 cm
SD - 1.5

Table 3.4-13 Sagebrush stem length (cm) as measured in October 1982. Site 7 .

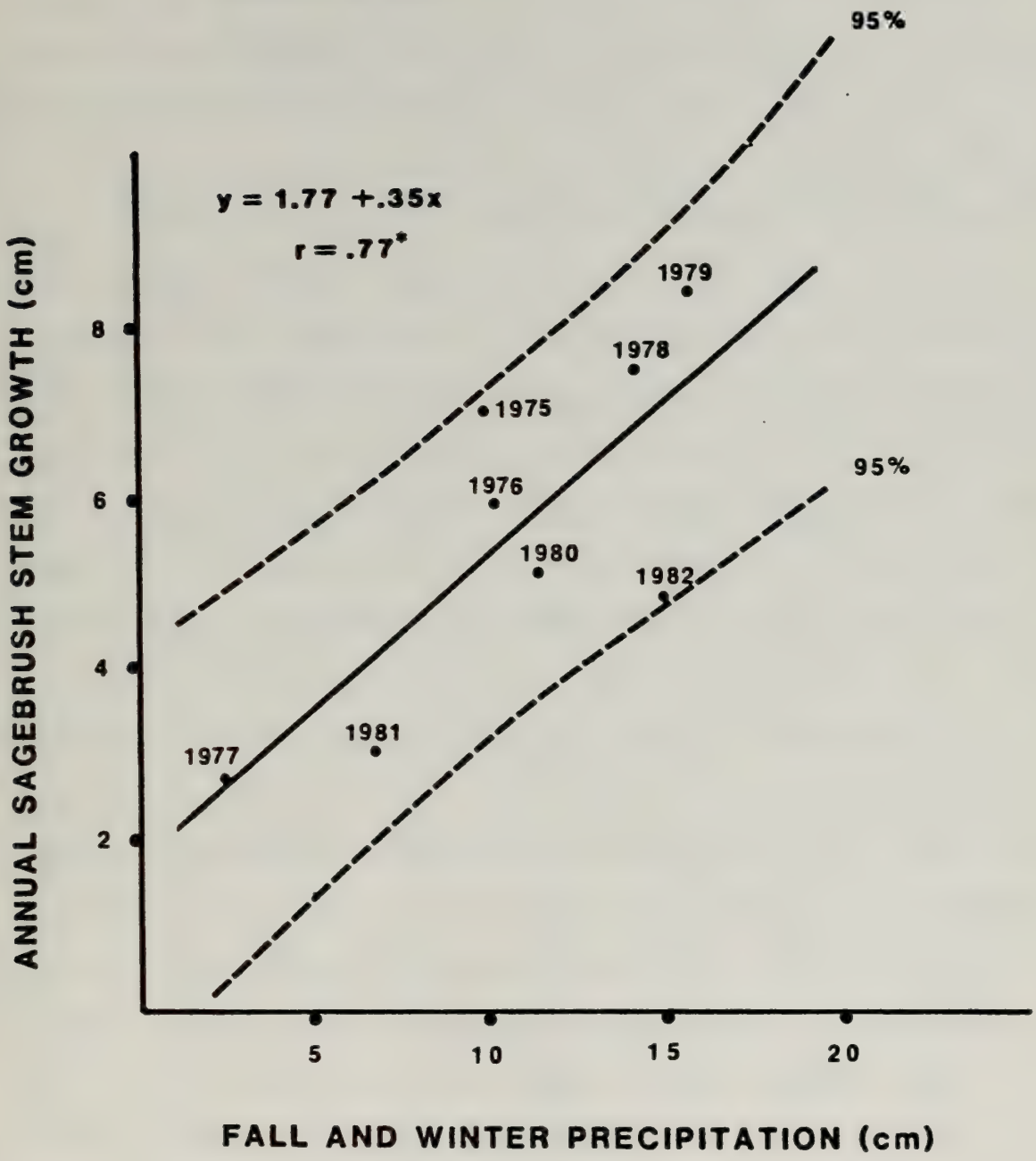
SAGEBRUSH STEM LENGTH (CM)

SHRUB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	$\bar{X}$ (cm)	SD
1	3.2	1.7	2.9	3.7	4.6	4.2	2.1	2.5	4.5	2.3	2.2	2.4	3.1	2.0	2.7	2.8	2.2	2.4	3.1	5.1	3.0	1.0
2	6.2	5.3	5.4	6.1	7.8	6.3	3.1	4.7	3.3	4.5	4.9	5.3	3.1	6.0	5.6	4.5	5.7	4.5	6.4	5.7	5.2	1.2
3	2.6	7.0	7.3	6.9	4.0	4.7	6.0	5.6	4.1	3.4	4.7	5.0	3.3	2.6	2.5	3.6	3.3	7.0	4.7	3.2	4.6	1.6
4	2.0	3.6	4.0	4.2	4.6	3.5	4.1	3.6	4.4	3.2	4.1	5.1	6.1	3.7	2.7	2.9	2.8	4.6	3.5	2.3	3.8	1.0
5	6.9	7.6	6.0	5.4	6.0	2.1	6.0	7.2	5.9	9.8	8.2	6.9	7.0	3.4	5.5	5.2	8.2	4.0	5.0	8.2	6.2	1.8
6	5.0	6.9	6.0	4.5	7.7	3.0	5.9	5.9	4.0	4.7	4.0	6.9	3.5	5.4	4.4	5.6	3.6	3.6	4.5	3.4	4.9	1.3
7	9.7	9.5	5.0	8.0	7.3	5.9	7.4	6.0	5.4	8.6	6.2	4.5	5.5	6.7	7.6	7.2	5.7	6.3	5.0	4.4	6.6	1.5
8	7.5	4.3	5.9	8.2	4.0	4.7	4.4	6.5	8.8	7.1	6.5	5.5	4.8	4.2	6.0	6.1	4.4	4.5	5.3	3.0	5.6	1.5
9	10.6	9.0	9.2	11.5	7.4	9.0	8.6	6.2	9.4	9.0	14.0	11.0	5.8	7.3	6.7	2.9	5.0	5.5	5.6	3.3	7.9	2.8
10	7.1	5.5	4.5	6.3	8.4	8.0	4.6	5.4	5.9	4.8	8.0	6.1	3.7	7.0	4.1	4.2	7.0	5.8	5.7	3.7	5.8	1.5
11	3.9	4.0	3.9	2.9	2.0	5.0	6.0	4.0	4.6	2.0	2.6	3.7	3.0	4.1	4.0	2.8	2.9	1.9	3.0	2.8	3.5	1.1
12	6.2	3.7	4.6	7.1	7.6	5.3	6.6	11.7	7.1	6.0	5.6	6.0	4.2	5.4	7.4	6.7	3.3	3.5	7.1	3.5	5.9	2.0
13	5.1	3.7	2.9	3.3	5.7	4.1	4.8	6.2	3.6	4.0	3.2	5.2	6.6	7.2	3.0	5.0	3.0	4.3	7.1	2.6	4.5	1.4
14	7.2	4.2	2.9	6.3	8.1	5.6	3.7	4.7	6.5	4.2	4.5	7.9	7.5	9.6	10.1	7.0	8.1	5.1	7.6	4.2	6.3	2.0
15	5.7	8.9	4.1	8.2	9.2	3.5	8.0	7.2	6.3	8.0	3.2	4.2	3.6	4.1	3.8	6.3	3.5	5.5	4.6	3.7	5.6	2.0
16	7.9	6.4	8.3	5.2	7.3	4.3	8.6	6.2	6.3	7.6	9.2	7.1	6.0	8.1	9.2	6.1	4.6	8.1	6.7	3.7	6.8	1.6
17	6.2	8.6	3.8	4.5	4.6	4.9	7.9	6.0	8.3	4.0	8.5	3.6	5.7	8.1	6.1	3.6	4.2	6.1	5.7	5.0	5.8	1.7
18	4.9	5.3	4.2	3.5	4.2	4.1	7.3	5.3	3.2	9.1	5.5	4.8	6.5	3.1	4.5	3.8	5.2	7.2	4.0	6.0	5.1	1.5
19	6.7	5.1	4.6	8.5	7.8	7.9	5.0	11.0	7.1	6.4	2.7	7.1	7.6	8.1	5.6	9.2	7.9	5.1	5.6	6.4	6.8	1.9
20	8.4	7.1	7.3	6.5	10.3	4.2	3.0	7.1	8.4	8.6	7.2	5.6	5.7	10.3	4.6	5.8	7.6	6.5	4.0	7.3	6.8	1.9

Site Location: $\bar{X}$ - 5.5 cm

SD - 1.2

Figure 3.4-2. Regression of sagebrush stem growth and fall and winter precipitation (ARA-13). The dashed lines represent the 95% prediction level.



(see Figure 3.4-2).

Average stem length ranged from 3.0 cm at site 5 on the east edge of Tract Ub to 5.9 cm at site 3 which is on the west side of Tract Ua (Table 3.4-14). The standard deviations for all seven sites are quite uniform which illustrates that the variability of stem growth is low.

Over the eight years of study, sagebrush stem growth ranged from 2.7 cm in 1977 to a high of 8.4 cm in 1979 (Table 3.4-14). The data for 1982 on sagebrush leader growth (4.8 cm) was the third lowest value recorded during this time period. An analysis of variance (ANOVA) was performed on the data (Sites 1-6) for the eight years of record. The results, shown in Table 3.4-15, point out that there was significant difference between years. The results of the LSD mean separation test are shown in Table 3.4-7. An ANOVA test comparing sites also showed significant differences. Site 3 had significantly longer stem lengths than any of the other sites. The results of the LSD test are also shown in Tables 3.4-14 and 3.4-15. Sagebrush leader growth appears to provide a realistic index of the year-to-year variability that occurs within the oil shale tracts and provides a good monitoring device to estimate plant variability within the ecosystem. However, as evidenced by the 1982 data, the relationship does not take into account all the variability in the system. Thus, the 95% predictive level will be used to identify outlier values that may occur in future years.

In addition to the leader growth measurements for sagebrush, measurements for three other species, fourwing saltbush (*Atriplex canescens*), rabbitbrush (*Chrysothamnus greenii*), and greasewood (*Sarcobatus vermiculatus*) were

Table 3.4-14. A comparison on sagebrush stem growth over an eight year period, 1975 to 1982 on sites related to prototye oil shale tracts Ua and Ub. Each value is generally the mean length of 20 stems on 20 plants (i.e., 400 observations/site/year). Values are expressed in centimeters. Averages followed by a common letter are not significantly different as analyzed by ANOVA with = .05 and LSD mean separation tests.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Average
1975								
Mean	7.4	6.9	9.7	5.6	7.1	5.4		7.0^{cd}
SD	2.14	1.12	1.36	1.03	1.31	1.5		
1976								
Mean	6.2	6.16	7.0	5.5	5.4	4.8		5.9^{bc}
SD	1.04	1.63	0.88	1.06	1.17	1.08		
1977								
Mean	2.1	2.0	4.0	2.2	2.8	2.8		2.7^{a}
SD	0.35	0.25	1.02	0.25	0.59	0.56		
1978								
Mean	8.4	8.1	10.1	6.4	5.6	6.5		7.5^{dc}
SD	1.76	2.88	2.16	1.10	1.59	2.52		
1979								
Mean	7.6	9.9	9.9	8.2	7.3	7.7		8.4^{e}
SD	2.0	2.2	2.5	2.1	1.8	1.9		
1980								
Mean	4.6	6.4	7.5	4.8	3.9	3.6		5.1^{b}
SD	1.4	1.9	1.7	1.3	1.1	1.0		
1981								
Mean	2.8	3.3	3.1	2.8	2.2	2.8	3.9	3.0^{a}
SD	0.8	0.7	0.6	0.5	0.5	0.5	0.8	
1982								
Mean	4.5	5.2	5.9	4.8	3.0	4.8	5.5	4.8^{b}
SD	1.2	1.4	1.1	1.1	0.6	1.5	1.2	
AVERAGE	5.5^{fg}	6.0^{g}	7.2^{h}	5.0^{f}	4.7^{f}	4.8^{f}		

Table 3.4-15 Two-Way Analysis of Variance test of sagebrush stem growth for 1975 through 1982

	SS	df	M.S.	F-ratio
Years	186.6	7	26.7	46.2*
Sites	35.0	5	7.0	12.2*
Error	20.2	35	.6	
Total	241.8	47		

*significant at $\alpha = .01$

sampled in 1982. These species were sampled from site 7 only. One hundred samples were taken for each species. These results are shown in Table 4.3-16. Average leader growth was 17.3 cm ± 9.9, for fourwing saltbush, 14.7 cm ± 6.6 for rabbitbrush, and 7.3 ± 3.3 for greasewood. Rabbitbrush and fourwing saltbush averages are 3-4 times higher than the averages for sagebrush while the greasewood had roughly two times more growth than sagebrush. Comparisons of the 1981 data show that 1982 averages were all higher. Saltbush increased by 124%, sagebrush by 141% and greasewood by 236%. Thus, sagebrush which increased by 141% from 1981 to 1982 at site 7 appears, at least initially, to represent accurately the fluctuations of other shrubs to environmental change. These species will be monitored again in 1983 to further document their yearly responses to changes. This will continue to provide information as to the suitability of sagebrush as a measure of general plant resources on oil shale tracts Ua and Ub.

3.4.3 Plant Chemical Composition

Sagebrush leaders from the seven sagebrush leader growth sites were analyzed for elemental content of several potentially harmful compounds. The parameters were analyzed to establish baseline measures for future comparisons to assess effects of processing operations. Nine parameters (Mo, As, Na, Ca, Mg, SO_4, Hg, Cd, and B) were analyzed from the sagebrush tissue. The parameters were selected because they may be present in quantities greater than normally encountered as a result of industrial development associated with oil shale (Stollenwerk and Runnells, 1981) and may accumulate to levels deleterious to plants or their consumers (Kilkelly and Lindsay, 1979; OTA

Table 4.3-16 Leader Growth measurements (cm) of fourwing saltbush, rabbitbrush, and greasewood from Site 7, October 1982, and comparison between 1981 and 1982 fourwing saltbush, sagebrush and greasewood leader growth (rabbitbrush replaced juniper in this year's analyses).

Rabbitbrush					Fourwing Saltbush					Greasewood				
Chry 1	Chry 2	Chry 3	Chry 4	Chry 5	Atca 1	Atca 2	Atca 3	Atca 4	Atca 5	Save 1	Save 2	Save 3	Save 4	Save 5
13.8	12.5	15.8	62.0	24.7	37	15	27	16	8	9.8	6.5	6.1	5.2	8.5
19.0	10,0	11.6	15.4	24.1	38	38	22	10	19	8.0	10.5	6.7	5.6	6.2
16.5	9.2	10.2	14.5	17.7	34	24	10	19	14	9.0	7.8	6.3	6.9	9.5
14.2	10.6	21.1	13.2	14.3	34	38	11	11	21	7.7	7.2	8.5	15.6	12.7
18.6	11.8	10.5	16.7	12.2	28	18	5	10	6	6.2	5.7	7.2	8.8	15.2
11.9	8.2	15.1	23.3	16.0	47	19	6	12	8	13.2	8.5	5.9	10.2	8.6
15.7	10.2	13.0	15.1	26.5	34	32	5	14	7	11.0	6.7	6.3	14.7	5.5
22.0	10.0	11.7	18.6	28.0	39	12	21	14	14	9.5	5.5	6.7	14.5	8.0
21.7	12.5	10.2	16.0	14.6	13	15	14	10	14	3.1	9.0	10.0	12.3	8.1
11.9	10.2	10.5	9.2	13.5	17	24	19	18	11	10.7	4.2	6.6	14.8	7.2
15.7	10.0	9.5	11.0	30	19	10	16	19	6	3.6	5.5	5.4	10.4	3.3
15.0	10.5	12.5	17.2	14	26	23	12	16	23	4.7	5.2	9.3	11.5	4.8
13.6	12.2	12.4	14.0	11.7	23	30	8	24	12	6.5	6.2	7.3	15.6	10.0
13.9	10.6	9.0	16.8	16	32	15	12	22	7	6.2	9.0	6.5	9.6	8.7
14.0	11.1	16.7	12.2	15	28	17	27	21	16	7.0	5.1	6.2	16.2	6.4
14.2	9.0	15.2	12.0	16.2	11	22	15	12	10	4.6	5.7	5.4	14.3	6.6
20.6	9.5	8.9	12.4	23.3	21	5	6	18	13	6.5	6.0	6.4	12.8	8.6
13.2	9.5	13.3	10.9	14.2	33	16	3	20	4	5.6	7.0	7.5	11.3	6.7
19.5	9.1	9.7	11.5	13.7	25	15	5	11	7	12.5	6.7	8.2	12.7	9.3
18.0	10.0	8.7	13.8	13.5	33	15	6	8	7	4.7	8.4	7.8	10.8	8.4
$\bar{x}$ 14.7 cm SD. 6.6					$\bar{x}$ 17.3 cm SD. 9.9					$\bar{x}$ 7.8 SD. 3.3				

Comparison

	Atca		Save		ARTR	
	1981	1982	1981	1982	1981	1982
$\bar{x}$	14.0	17.3	3.3	7.8	3.9	5.5
SD	6.3	9.9	1.9	3.3	.8	1.2

1980).

Values reported from the analyses performed in 1982 are compared with 1981 data in Table 3.4-17. Differences between years may be the results of different labs since two labs were used. The 1982 samples are being rerun to determine if the variation is due to yearly changes or lab differences. The values shown represent composite samples of 12 leaders per site. All of the values obtained thus far are within the normal range of concentrations within plants as reported by Gough et al. (1979).

3.4.4 Litterfall Measurements

The amount of litter returning to the soil is closely related to production of plant biomass for a given year. Litterfall is being measured under the canopy of the dominant shrubs and juniper trees on the tracts. Measurements of litterfall are important because excessive litterfall of leaves and twigs from shrubs and juniper may indicate undue stress of plants (excess litterfall has been observed in areas of air pollution). Litterfall is also essential to the normal functioning of many soil parameters and to many small animals. The area around shrubs where the litter accumulates is the nutritional "storehouse" for arid plant communities (Garcia-Moya and McKell, 1970; Bjierregard, 1971) and any significant change in litterfall would result in changes in many ecosystem functions.

Litter traps were constructed in late spring and placed under the shrub species during the June sampling period. A total of 242 littertraps were placed. Each species (seven total) had 30-40 traps or replications placed beneath its canopy (Table 3.4-18). The seven species sampled were sagebrush,

Table 3.4-17 Comparisons of 1981 and 1982 elemental analysis of sagebrush leaders collected from the seven sagebrush leader growth sites.

Site	Mo(ppm)		As(ppm)		Na (%)		Ca(%)		Mg(ppm)		SO_4(%)		B(ppm)		Hg(ppb)		Cd(ppm)	
	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982
SLG 1	.83	<25	0.3	12.5	.275	.115	.490	.543	870	901	.18	.13	40	14	15	>10	12.5	<1.3
" 2	.70	<25	0.4	12.5	.486	.103	.445	.533	930	960	.23	.08	26	11	9	>10	14.8	<1.3
" 3	1.00	<25	0.2	12.5	.535	.086	.430	.507	760	973	.17	.10	19	16	2	>10	4.0	<1.3
" 4	.63	<25	0.3	12.5	.490	.056	.450	.526	850	992	.23	.27	22	9	30	>10	1.7	<1.3
" 5	.35	<25	0.4	12.5	.305	.159	.445	.491	930	1198	.21	.10	22	13	18	>10	1.1	<1.3
" 6	.50	<25	0.4	12.5	.305	.119	.405	.594	790	942	.19	.07	25	15	7	>10	1.0	<1.3
" 7	.63	<25	0.2	12.5	.296	.077	.430	.477	760	906	.22	.03	25	15	25	>10	1.0	<1.3
$\bar{x}$	.66	<25	0.3	12.5	.389[a]	.102[b]	.442[a]	.524[b]	841[a]	982[b]	.20[a]	.11[b]	26[a]	13[b]	15	>10	5.2	<1.3
s	.21		0.09		.110	.033	.026	.039	74	101	.02	.08	6.8	2.5	10		5.9	

Table 3.4.18. General locations of species receiving litter fall catchments.*

	Species							
Location[1]	ARTR	ATCA	ATCO	CHGR	GRSP	JUOS	SAVE	Subtotal
VS-1	4		10					14
VS-4	2		6					8
VS-5		9	6					15
VG-1	6	5		6	6		7	30
VG-2					6		6	12
VG-3	6			6			6	18
VG-4	6		5	6	7			24
VG-5	6		6	6			6	24
VJ-1						10		10
VJ-2						10		10
IN-1		10						10
HE-3		6				11		17
SLG-1							5	5
SLG-4				5	8			13
SLG-6	6		6	6	8		6	32
TOTAL	36	30	39	35	35	31	36	242

[1]15 sites

*Supersedes page 9, January 1982-June 1982 Monitoring and Research Semi-Annual Report (July 1982).

fourwing saltbush, shadscale (Atriplex confertifolia), Greenes rabbitbrush (Chrysothamnus greenii), hopsage (Grayia spinosa), Utah juniper, and greasewood. The litter traps were rectangular in shape with dimensions of 50 cm x 100 cm or $\frac{1}{2}m^2$ (Figure 3.4-3). The sides of the traps were 16 cm in height to prevent litter from blowing out of the traps. The bottom of the traps consisted of a fine mesh window screen which is small enough to catch most of the litter fragments but will allow water to pass through and prevent decomposition. The 1981 litter traps did not have a fine enough screen for the six shrubs but they were suitable for juniper. Thus, the 1981 traps were utilized exclusively under juniper. The new $\frac{1}{2}m^2$ traps could be joined together to form a complete trap around a shrub. Analysis were performed to compare if $\frac{1}{2}m^2$ traps were proportional to $1m^2$ traps. The typical placement of the $1m^2$ litter traps is shown in Figure 3.4-4. A size index for each plant was also calculated so adjustments or comparisons could be made in litterfall from small or large plants. The size index is computed by multiplying the height by the crown diameter (in two directions). This approximates a volume figure which can then be used to compare between differing sized individuals as well as between different sized species.

The litter traps were revisited in October and the litter for that period (June-October) was removed, placed in bags and the traps replaced. The litter samples were taken to the lab, oven dried for 14 days at 25°C. The litter was separated into components, leaf, stem, seed, inflorescence of mixtures of each and then weighed. The results for the weights for each species and size indices are shown in Table 3.4-19-25. A summary table (Table 3.4-26) shows

Figure 3.4 -3. Typical placement of a $\frac{1}{2}m^2$ trap under shadscale

Figure 3.4 -4. Placement of two $\frac{1}{2}m^2$ litter traps under sagebrush.

Table 3.4-19. Results of litter fall data and size indices for sagebrush (ARTR), 1982.

Location	Shrub Number	Catchment Size*	1	2	3	4	5	Composition of litter fall (gm) 6	7	8	9	10	11
VG-4	10	2	0.60	0.66	0.66	0.26	31	31					
	11	2	0.53	0.90	0.82	0.39	56	54	2				
	13	1	0.56	0.75	0.58	0.24	17.5	17	0.5				
	14	1	0.53	0.84	0.66	0.29	24	23	1				
VG-3	2	2	0.70	0.97	0.82	0.56	36.6	36	0.6				
	9	1	0.38	0.60	0.48	0.11	10.1	10	0.1				
	10	1	0.46	0.95	0.60	0.26	14	13	1				
	11	2	0.57	0.94	0.92	0.49	80	79	1				
VG-5	4	2	0.38	0.89	0.58	0.20	20	17	3				
	5	1	0.45	0.60	0.45	0.12	5.4	5	0.4				
	6	1	0.38	0.53	0.38	0.08	8	7	1				
	7	2	0.44	0.83	0.64	0.23	12	11	1				
VS-4	4	2	0.35	0.87	0.60	0.18	52	51	1				
VG-1	5	2	0.83	1.03	0.85	0.73	51	50	1				
	8	1	0.68	0.57	1.12	0.43	17	14	3				
	10	1	0.84	1.11	0.78	0.73	19.5	19	0.5				
	16	2	0.81	0.82	0.69	0.46	48	47	1				
VS-1	1	1	0.44	0.78	0.57	0.20	16.2	16	0.2				
	2	1	0.46	1.03	0.70	0.33	36	35	1				
	3	2	0.36	0.70	0.60	0.15	18	17	1				
SLG-6	1	2	0.63	1.05	0.91	0.60	85	80	5				
	3	1	0.60	1.30	0.90	0.70	36	33	3				
	6	1	0.54	0.96	0.80	0.42	40	38	2				
	8	2	0.62	1.13	1.05	0.74	69	65	4				

1 - Height (m)
2 - Width 1 (m)
3 - Width 2 (m)
4 - Size index (m^3)
5 - Total litter fall (gm)
6 - Leaf
7 - Stem
8 - Seed
9 - Inflorescence
10 - Leaf and stem
11 - Mixtures, L, Se, St, I
* 1 = $1m^2$ traps
2 = $1m^2$ traps

Table 3.4-20. Results of litter fall data and size indices for fourwing saltbush (ATCA), 1982.

Location	Shrub Number	Catchment* Size	1	2	3	4	5	Composition of litter fall (gm) 6	7	8	9	10	11
VS-5	2	1	1.12	1.36	1.75	2.67	--**						
	3	2	0.94	2.00	1.68	3.09	93	44	6	43			
	4	2	1.26	1.77	1.92	4.28	110	60	9	41			
	9	2	0.73	1.15	0.80	0.67	--**						
	1	2	0.81	2.08	1.70	2.86	43	30	6	7			
VG-1	2	1	0.78	1.82	1.42	2.02	38	21	13	4			
	3	1	0.69	0.98	1.16	0.78	37		2	20		15	
	7	2	0.49	0.64	0.58	0.18	45	17	28				
	19	1	0.85	0.66	0.42	0.24	70		10	41			19
IN-1	1	2	0.62	1.11	0.92	0.63	31.2	21	10	0.2			
	2	2	0.70	0.91	0.45	0.29	23	12	3	8			
	3	1	0.82	1.47	0.88	1.06	19		10	2		7	
	4	2	0.68	1.39	1.51	1.43	25	15	10				
	5	2	0.57	0.74	0.75	0.32	49	18	7	24			
	6	1	0.71	0.58	0.63	0.26	20	16	2	2			
HE-3	5	1	0.46	0.82	0.52	0.20	10.3	9	0.3	1			
	6	1	0.98	1.31	1.13	1.45	7.5	5	2	0.5			
	9	2	0.94	1.55	1.36	1.98	73	28	23	22			
	10	2	1.44	1.36	2.22	4.35	42	28	2	12			

**no collection

Table 3.4-21. Results of litter fall data and size indices for shadscale (ATCO), 1982.

Location	Shrub Number	Catchment* Size	1	2	3	4	5	Composition of litter fall (gm) 6	7	8	9	10	11
VS-1	4	1	0.28	0.74	0.70	0.15	18	15	3				
	5	1	0.26	0.60	0.52	0.08	10.2	10	0.2				
	6	1	0.27	0.70	0.51	0.10	15		2			13	
	7	2	0.49	0.65	0.57	0.18	20	19	1				
	8	2	0.21	0.50	0.46	0.05	10.4	10	0.4				
	9	2	0.39	0.71	0.54	0.05	14		1			13	
	10	1	0.58	0.66	0.54	0.21	17	16	1				
SLG-6	4	1	0.44	0.64	0.47	0.13	13		2			11	
	15	2	0.53	0.89	0.75	0.35	36		10				26
	22	2	0.54	0.84	0.68	0.31	54	47	7				
	24	1	0.37	0.67	0.66	0.16	23		2			21	
VS-5	5	2	0.31	0.56	0.58	0.10	17	14	3				
	6	1	0.22	0.57	0.38	0.05	20	19	1				
	7	2	0.36	1.88	1.60	1.08	18	16	2				
	8	1	0.28	0.53	0.50	0.07	14	13	1				
VG-5	1	1	0.37	0.60	0.38	0.08	13		2			11	
	3	1	0.37	0.72	0.54	0.14	13	1	12				
	9	2	0.54	0.79	0.65	0.28	25	21	4				
	16	2	0.56	0.72	0.68	0.27	16		2			14	
VS-4	1	2	0.41	0.75	0.66	0.20	28		3				25
	2	1	0.31	0.42	0.36	0.05	7.3		0.3				7
	3	2	0.34	0.89	0.54	0.16	34		4			30	
	5	1	0.41	0.47	0.42	0.08	12		1				11
VG-4	6	2	0.44	0.72	0.62	0.20	19		3			16	
	9	2	0.38	0.73	0.64	0.18	15	14	1				
	12	1	0.38	0.64	0.52	0.13	8.4	8	0.4				

Table 3.4-22. Results of litter fall data and size indices for rabbitbrush (CHGR), 1982.

Location	Shrub Number	Catchment* Size	1	2	3	4	5	Composition of litter fall (gm) 6	7	8	9	10	11
SLG-6	2	2	0.55	0.84	0.73	0.34	24		13				11
	17	1	0.77	1.48	1.35	1.54	42		8		21		13
	18	2	0.64	1.22	1.05	0.82	37		14				23
	19	1	0.45	0.70	0.49	0.14	7		1				6
VG-3	1	2	0.50	0.87	0.69	0.30	6		3				3
	4	1	0.48	0.68	0.55	0.18	1						1
	6	2	0.41	0.76	0.68	0.21	10		10				
	7	1	0.36	0.65	0.59	0.14	1						1
VG-5	11	2	0.56	1.02	0.87	0.50	6		4				2
	12	1	0.47	0.85	0.73	0.29	1.5		1				0.5
	13	1	0.59	0.60	0.57	0.20	0.3		0.3				
	14	2	0.52	1.02	0.75	0.40	4		2				2
VG-4	7	1	0.53	0.76	0.66	0.27	1.5		0.5				1
	8	1	0.44	0.64	0.63	0.18	10		9				1
	15	2	0.46	0.78	0.61	0.22	1						1
	16	2	0.47	0.90	0.88	0.37	7		3				4
SLG-4	1	2	0.38	0.62	0.62	0.15	6		2				4
	2	2	0.74	1.02	1.25	0.94	16		6		10		
	4	1	0.47	0.82	0.61	0.24	2.5		0.5				2
VG-1	1	2	0.49	0.88	0.92	0.40	13		1		12		
	4	1	0.54	0.83	0.74	0.33	7		2		5		
	11	2	0.63	0.55	0.49	0.17	15		4		11		
	13	1	0.67	0.75	0.74	0.37	22		4		18		

Table 3.4-23. Results of litter fall dat and size indices for hopsage (GRSP), 1982.

Location	Shrub Number	Catchment* Size	1	2	3	4	5	Composition of litter fall (gm) 6	7	8	9	10	11
SLG-6	12	1	0.55	0.78	0.70	0.30	26	21	5				
	13	2	0.47	1.03	0.91	0.44	25		11			14	
	14	1	0.44	0.74	0.58	0.19	9	7	2				
	16	2	0.44	0.90	0.79	0.31	27	6				21	
	20	2	0.59	1.03	0.91	0.55	50		15			35	
VG-2	5	2	0.40	0.84	0.78	0.26	12	6	6				
	6	1	0.56	1.37	1.18	0.91	12	8				4	
	7	1	0.60	1.22	1.00	0.73	7	6	1				
	8	2	0.55	1.05	1.03	0.60	63		7			56	
VG-4	1	2	0.44	0.78	0.60	0.21	11		4			7	
	2	1	0.42	1.10	0.91	0.42	14		8			6	
	3	2	0.42	0.72	0.70	0.21	14	11	3				
	4	1	0.45	0.88	0.82	0.33	6		3				3
	5	1	0.40	0.79	0.71	0.22	8		5				3
SLG-4	3	1	0.62	0.89	0.63	0.35	15	13	2				
	5	1	0.59	0.88	0.69	0.36	27	20	7				
	6	2	0.68	0.76	0.98	0.51	60	56	4				
	7	2	0.47	0.83	0.68	0.27	38	37	1				
	8	2	0.64	0.84	0.88	0.47	46	43	3				
VG-1	12	2	0.58	0.67	0.62	0.24	7	6	1				
	14	1	0.77	1.40	1.00	1.08	24	23	1				
	20	2	0.52	0.94	0.83	0.41	32	5					27
	21	1	0.53	0.96	1.02	0.52	24	23	1				

Table 3.4-24. Results of litter fall data and size indices for greasewood (SAVE), 1982.

Location	Shrub Number	Catchment* Size	1	2	3	4	5	Composition of litter fall (gm) 6	7	8	9	10	11
SLG-6	7	1	0.84	1.25	0.98	1.03	30		5			25	
	11	2	0.77	0.90	0.84	0.58	27		6			21	
	21	2	0.66	1.03	0.87	0.59	50		24			26	
	23	1	0.69	0.78	0.44	0.24	18		6			12	
VG-3	3	2	1.25	1.30	0.87	1.41	43		20			23	
	5	1	0.73	1.02	0.89	0.60	10	8	2				
	8	1	0.56	0.95	0.92	0.49	8		4			4	
	12	2	0.50	0.80	0.40	0.16	8		6			2	
VG-5	2	2	1.17	1.88	1.59	3.50	62		18			44	
	8	2	0.80	1.14	0.87	0.79	36	33	2	1			
	10	1	0.83	1.04	1.04	0.90	15		6			9	
	15	1	0.79	1.21	1.12	1.07	9		1				8
SLG-1	1	2	0.98	1.44	1.49	2.10	33		4				29
	2	1	0.89	1.37	1.05	1.28	5						5
	3	2	0.79	0.82	0.88	0.57	14		4				10
VG-2	1	2	0.77	1.01	0.69	0.54	46	37	9				
	2	2	0.50	0.78	0.57	0.22	42		20			22	
	3	1	0.58	0.73	0.54	0.23	22		8			14	
	4	1	0.77	0.88	0.78	0.53	19	15	4				
VG-1	1	2	0.98	0.94	0.62	0.57	45	34	11				
	9	2	0.99	1.14	1.15	1.30	108		10				98
	15	1	0.74	0.76	0.48	0.27	33	17	16				
	17	1	0.75	0.73	0.53	0.29	--**						
	18	1	1.32	2.00	1.65	4.36	49	45	4				

**no collection

Table 3.4-25. Results of litter fall data and size indices for juniper (JUOS), 1982.

Location	Shrub Number	Catchment* Size	1	2	3	4	5	Composition of litter fall (gm) 6	7	8	9	10	11
HE-3	1	2	2.15	1.94	1.52	6.34	268	266	2				
	2	2	2.70	1.70	1.23	5.65	32	28	4				
	3	1	2.79	2.82	2.44	19.20	104	96	7	1			
	4	2	2.83	1.98	2.26	12.66	161	157	3	1			
	7	2	2.06	2.05	1.85	7.81	60	56	2	2			
	8	2	3.52	2.47	3.12	27.13	236	203	7	26			
VJ-2	1	2	2.70	4.50	3.20	38.88	160	146	7	7			
	2	2	1.90	2.60	2.30	11.36	77	69		8			
	3	2	2.80	2.80	2.50	19.60	77	69	5				
	4	2	1.95	2.90	2.40	13.57	217	209	8				
	5	2	2.25	2.30	2.15	11.13	76	68	8				
VJ-1	1	2	3.90	2.95	2.70	31.06	81	77	4				
	2	2	2.45	1.70	1.40	5.83	54	51	3				
	3	2	3.20	1.90	1.80	10.94	47	45	2				
	4	2	3.40	2.80	2.70	25.70	64	60	4				
	5	2	2.65	2.60	1.80	12.40	86	80	6				

Table 3.4-26. Litterfall composition, Total litterfall, size indexes, and total litter per size index for each of the seven species studied for the period June-October 1982.

Species	%Leaf	%Stem	Stem Leaf	%Seed	Inflor.	Mixtures	Total/m^2	SI	gm litter/SI
ARTR*	95	5					45.04	.38	118.5
SAVE*	24	29	28			19	41.39	1.02	40.58
GRSP	48	24	19			8	32.00	.43	74.87
CHGR*		39			19	42	14.87	.38	39.54
ATCO*	44	10	25			21	26.36	.15	174.34
ATCA	51	21	2	22		4	54.35	1.41	38.42
JUOS	93	5		2			112.44	16.20	6.94

Table 3.4-27 Comparisons of litterfall data for 1981 and 1982. Since the litter traps differed both in shape and mesh of the screen between years direct comparison should not be made. Rather this table illustrates the added effectiveness of the newer traps.

	1981 gm/m^3	shrub ranking	1982 gm/m^3	shrub ranking
ARTR	17.8	3	118.5	2
SAVE	11.7	5	40.6	4
GRSP	28.9	2	74.9	3
CHGR	6.7	6	39.5	5
ATCO	36.8	1	174.3	1
ATCA	16.6	4	38.4	6

the percentage of litterfall for each component, total litterfall, size index, and grams of litter/cubic area of above ground tissue for each species. Litterfall measurement compares favorably to other values reported in the literature (West, 1979). Utah juniper had the greatest litterfall for a five month period. However, the plants were also the largest. On a per cubic unit basis, shadscale produced the most litter and was followed by sagebrush yielding equivalents of 174.3 g/m^3 and 118.5 g/m^3, respectively.

A comparison of results for 1981 with 1982 are limited since the litter traps change between years for all species except Juniper (Table 3.4-27). Comparisons can be made on the increased effectiveness of the new traps in collecting more litter. Litter volumes (g/m^3) increased from 200% for shadscale, a course shrub, to 660% for sagebrush, which has finer litter, from 1981 to 1982. The litterfall traps (which were kept the same) decreased in 1982 from 1981 although the decrease was small and not statistically significant (123g in 1981 and 112g in 1982 - based on $1m^2$ plots).

3.4.5 Assessment of Animal Use of Plants

The monitoring of animal use of plants is important during the construction and operational phase of the White River Shale Project. Impacts of the operation on browsing animals may be reflected through their use of browse shrub species (i.e., heavier or lighter utilization than the average usage).

To assess the use on the tracts, the Cole Browse Survey was run at six sites using three key species in June of 1982. Utilization was difficult to determine at this time on two of the key species; shadscale (*A. confertifolia*) and greasewood (*S. vermiculatus*) and appeared to be too subjective to be very

reliable. Utilization was difficult to determine because two year old terminal scars were not visually apparent and new leaders had begun growth. It was also decided that in addition to the Cole Survey that an actual measurement of clipped (browsed) herbage, that can be converted to kg/Hectar of utilization, would be taken. This will complement the Cole Survey and allow greater precision in measuring the percent utilization which is subject to sampler bias using the Cole Survey. Utilization of herbage production will be measured by comparing enclosed and non-enclosed shrubs.

Two key species, sagebrush (A. tridentata) and fourwing saltbush (A. canescens) have been identified by the Department of Wildlife Resources as providing winter browse in the White River area (Pershon, personal comm., 1982). Only sagebrush will be monitored because fourwing saltbush shrubs are too scattered to obtain a sufficient sample within the area. On October 8, 1982, twenty individual sagebrush plants were enclosed with chicken wire. Ten of the cages were placed at site SLG 6 and at VG 1. In March of 1983 caged and non caged shrubs will be observed for browse utilization by measuring leader length. At this time sample adequacy will be determined and sample size of caged shrubs will be adjusted.

Results of the Cole Browse Survey taken in June, 1982 are given in Table 3.4-28. Although sampling results may not be very reliable, they were interpreted and a discussion of the interpretation follows. Sagebrush received heavier leader usage (66%) than shadscale (47%) and greasewood (40%). Form class is an indication of browsing received the previous two years. Sagebrush again received the heaviest usage, 58% of the shrubs were heavily

Table 3.4.28. Results of the Cole Browse Survey taken in June, 1982.

Species, Sample Site	Form Class - Hedging (%)			Age Class (%)				Leader Use (%)
	None	Light to Moderate	Heavy	Seedling	Young	Mature	Decadent	
A. confertifolia								
VS 5	36	64	0	0	0	92	8	13
VS 1	0	28	72	0	0	88	12	81
$\bar{x}$	18	46	36	0	0	90	10	47
A. tridentata								
VG 1	0	32	68	8	16	72	8	72
VG 2	0	52	48	0	0	88	12	60
$\bar{x}$	0	42	58	4	8	80	10	66
S. vermiculatus								
VG 4	28	64	8	0	4	92	4	20
VG 3	0	60	40	0	0	76	24	60
$\bar{x}$	14	62	24	0	2	84	14	40

used (Figure 3.4-5). Form class and age class together may indicate the allowable browse usage of a particular species. Shadscale had 10% of the plants within the decadent age class and none in the seedling or younger age class. If this trend continues for several years it may indicate that browsing pressure (36% heavy usage) has been too heavy to allow young plants to mature. Likewise, greasewood had 24% of the plants in the heavily hedged class and 14% were decadent and only 2% in the young age class. Sagebrush apparently has a greater tolerance to grazing and can tolerate 58% heavy hedging. The young and seedling age class (12%) was greater than decadence (10%). If these trends continue, it may indicate that grazing pressure is too heavy for some of the browse species.

A visual assessment of browse usage made in October of 1981 was reported to be very light (0-5%). In June, 1982 an assessment of browse usage was made using the Cole Browse Survey Method and average usage was 51 percent. This difference is due primarily to June versus October sampling as well as to a more accurate sampling method. Generally, animals graze on grasses and forbs during the summer months and take very few shrubs. This is the time when shrubs are developing new leaders. Sampling in October reflects this summer usage of shrubs which is low, and evidences of past (winter) grazing are hidden by the new growth.

Browse utilization sampling in June was also difficult due to leader regrowth. Therefore, in 1983 all sampling will be done in late March. In addition to the Cole Browse Survey, caged plots will be monitored in March 1983 and methods compared.

Figure 3.4-5. Illustration of browse usage of sagebrush. June, 1982.

3.4.6 Use of Lichens as Biological Monitors of Air Pollution

The use of lichens as indicators of air quality has been documented and in many cases implemented throughout many parts of the world (refer to Ferry et al., 1973 for a detailed treatment). The use of lichens to monitor the effects of air pollution is attributed to several factors. One is that many lichen species rapidly accumulate toxic substances (Richardson nad Nieboer, 1981). With the accumulation of a particular one of these substances comes a reduction in photosynthetic, respiration and nitrification rates (Henriksson and Pearson, 1981). Both the concentration levels and the levels of cellular activity of the lichen symbionts can be measured and compared to normal or standard conditions. This provides a micro-level of detection of not so much the concentrations of toxic elements, but the effect of those concentrations on cellular activity, which is the more pertinent information. It has been noted that lichens are more sensitive to air pollutants than are vascular plants (Eversman, 1978) and, therefore, any detectable damage to lichens serves as an early indicator of potential pollution damage to vascular species.

The purpose of this phase of the monitoring program is to first, document the existing conditions of the saxicolous lichen community within the proposed development area of the White River Shale Project. A second objective is to develop procedures/methodology for measuring the degradation of the lichen communities and any damage to lichen tissues that may occur from increased atmospheric concentrations of toxic elements, in particular SO_2, resulting from oil shale development activities.

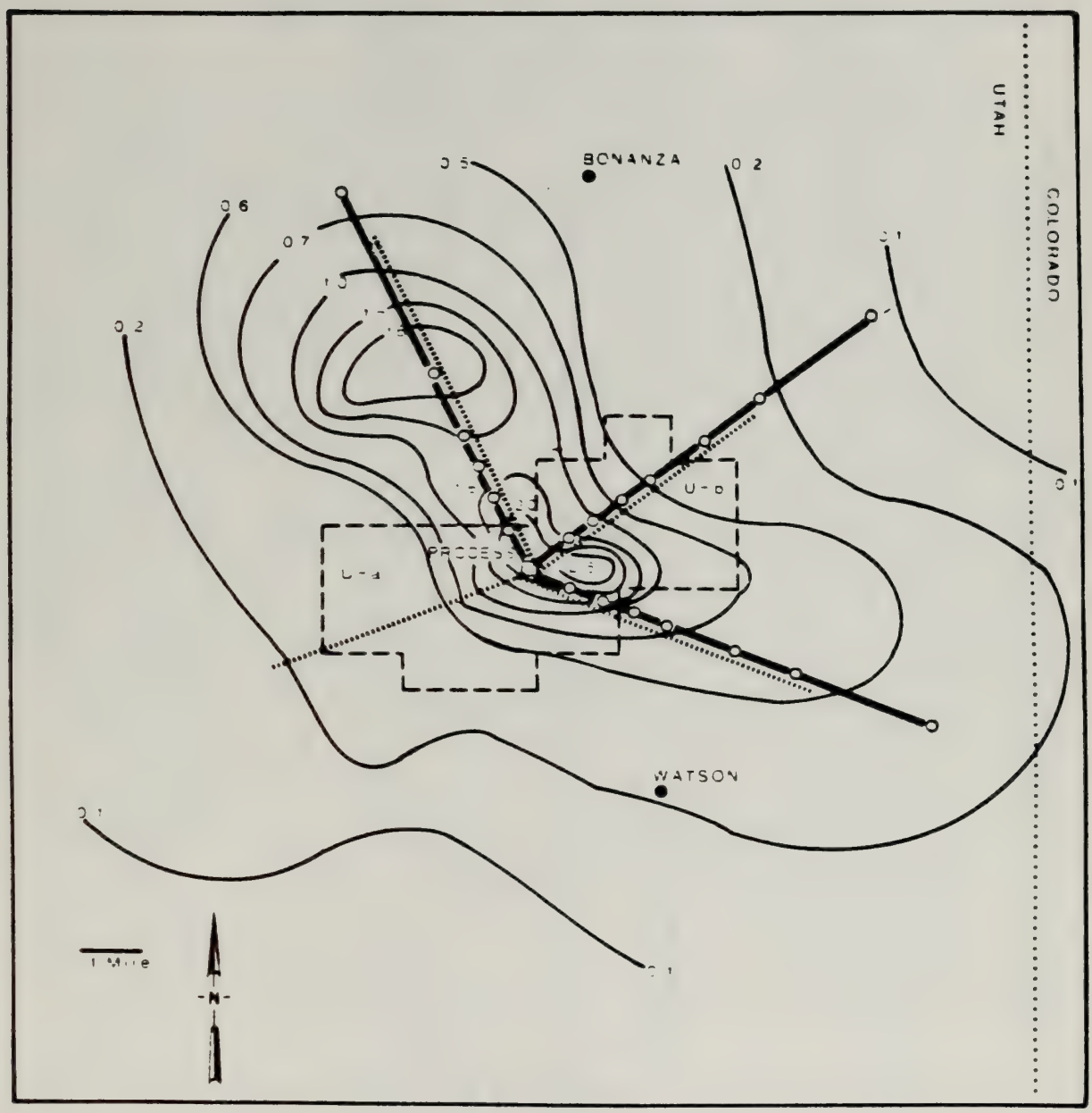
Characterization of selected saxicolous lichen communities along three

transects radiating out from the proposed plant site (Figure 3.4-6) was initiated with 1982 field studies. The data collected are presented in Tables 3.4-29 and 3.4-30. The data represent a summary of the parameters measured at each stand. The total cover values represent an ocular estimate of the cover attributable to both lichens and mosses. Cover values for the NW transect vary from 12.8 at stand 3 to 25.7 at stand 5. The variation of cover between stands along the NE & SE transects is about the same, ranging from 24.6 to 48.3 and 25.3 to 42.4,respectively. It can also be noted that the amount of cryptogamic cover was somewhat higher along the NE & SE transects than the NW transect. Statistical comparisons are not appropriate between transects or between stands since variables such as substrate and exposure were not considered when locating stands. The experiment was designed to measure changes at each stand over time. The data presented in Table 3.4-29 do, however, give an indication of the development of the saxicolous lichen communities along each transect.

As explained in the quarterly report, the saxicolous lichen Lecanora peltata was selected as the indicator species due to its presence along each transect. The amount of cover attributable to L. peltata and its frequency of occurrence fluctuated along the three transects. As can be seen, the standard deviation for the cover data exceeded the mean in all cases, which is indicative of the variability at each stand.

One parameter measured that was relatively consistent was the number of species encountered per quadrat. The values reported range from 6-9 species per quadrat and the variation at each stand was much lower in comparison with

Figure 3.4-6. Location of CIR transects and lichen monitoring transects with respect to representative annual average SO_2 concentrations.



Vegetation stress transects
Biological monitoring transect with stand locations.

Table 3.4 -29 Summary of ecological parameters measured and elemental analysis of lichen tissue and substrate material (standard deviation in parenthesis).

	Northwest						
	1	2	3	4	5	6	7
Distance from plant site(miles)	0.5	1.0	1.5	2.0	3.0	4.0	6.0
Total cover (%)	18.8 (13.27)	19.5 (14.04)	12.8 (7.33)	23.4 (14.43)	25.7 (19.24)	21.2 (15.26)	25.2 (15.19)
Cover *L. peltata* (%)	.15 (.31)	.36 (.93)	.16 (.36)	.42 (.59)	.37 (.48)	.38 (.57)	1.03 (1.28)
Freq. *L. peltata* (%)	40	25	25	55	55	55	70
# Spp/Quad	6.25 (1.74)	6.0 (2.10)	5.65 (1.69)	7.05 (2.39)	8.95 (2.80)	7.30 (3.01)	6.30 (1.45)
Sulfur *L. peltata* (ppm)	903 (5.77)	1050 (20.0)	807 (50.3)	860 (30.0)	840 (43.6)	523 (25.2)	1057 (352.3)
Fluorine *L. peltata* (ppm)	47 (7.6)	57 (18.9)	35 (5.0)	12.6 (47)	35 (8.7)	33 (10.4)	15 (17.3)
Sulfur substrate (ppm)	340 (10)	303 (5.8)	520 (20)	483 (23)	610 (26.5)	323 (20.8)	547 (5.8)
Fluorine substrate (ppm)	103 (33.3)	167 (58.6)	122 (20.2)	148 (10.4)	95 (35)	178 (74.2)	138 (28.4)

Table 3.4-29. (Continued)

	Southeast						
	1	2	3	4	5	6	7
Distance from plant site (miles)	0.5	1.0	1.5	2.0	3.0	4.0	6.0
Total cover (%)	32.3 (12.17)	25.3 (10.04)	25.3 (12.62)	26.1 (12.68)	42.4 (11.26)	30.1 (12.23)	--*
Cover *L. peltata* (%)	.25 (.72)	.56 (1.63)	.42 (.67)	.32 (.65)	.36 (.67)	.17 (.49)	--*
Freq. *L. peltata* (%)	.15	.25	.50	.35	.30	.25	--*
# Spp/quad	7.65 (1.31)	6.85 (1.76)	7.20 (1.54)	7.85 (2.03)	9.4 (1.43)	7.40 (1.35)	__*
Sulfur *L. peltata* (ppm)	680 (125.3)	593 (49.3)	713 (28.9)	823 (55.1)	977 (167.7)	1013 (30.6)	990 (45.8)
Fluorine *L. peltata* (ppm)	28 (5.8)	23(8.2)	23(11.5)	20 (4.4)	25 (0)	30 (10.5)	25 (0)
Sulfur substrate (ppm)	333 (5.8)	360 (17.3)	277 (20.8)	337 (5.8)	357 (11.5)	347 (5.8)	660 (17.3)
Fluorine substrate (ppm)	137 (45.1)	207 (23.1)	152 (25.7)	260 (43.6)	157 (70.2)	172 (69.3)	160 (32.8)

* Photoplot only

Table 3.4-29. (Continued)

	Northeast						
	1	2	3	4	5	6	7
Distance from plant site(miles)	0.5	1.0	1.5	2.0	3.0	4.0	6.0
Total cover (%)	31.4 (17.06)	34.8 (14.19)	28.6 (14.32)	24.6 (8.53)	48.3 (18.24)	--*	--*
Cover *L. peltata* (%)	.42 (.74)	.11 (.31)	.37 (.58)	.32 (.92)	.86 (.92)	--*	--*
Freq. *L. peltata* (%)	.55	.15	.45	.35	.65	--*	--*
# Spp/quad	8.15 (2.21)	7.95 (2.21)	8.10 (1.80)	8.15 (1.98)	1.22 (9.70)	--*	--*
Sulfur *L. peltata* (ppm)	760 (62.5)	827 (85.1)	637 (117.2)	723 (50.3)	663 (60.3)	740 (26.5)	1000 (10.0)
Fluorine *L. peltata* (ppm)	28 (31.9)	60 (8.7)	75 (20.0)	50 (10.0)	48 (15.3)	52 (10.4)	62 (2.9)
Sulfur substrate (ppm)	320 (17.3)	703 (15.3)	917 (30.6)	443 (15.3)	513 (11.5)	827 (80.8)	397 (5.8)
Fluorine substrate (ppm)	182 (67.1)	188 (45.4)	233 (65.1)	177 (50.3)	183 (11.5)	98 (30.1)	140 (36.1)

* Photoplot only

Table 3.4 -30. Frequency of all lichen species encountered along the SE transects.

Species	Stands 1	2	3	4	5	6	7*
Acarospora strigata	.50	1.0	.90	.65	.70	.85	
A. chlorophana	--	--	--	--	--	.20	
A. glaucocarpa	--	.15	--	.20	.35	.25	
A. schleicheri	--	--	--	--	--	--	
A. smaragdula	.60	.25	.20	.25	.75	.35	
Buellia punctata	.20	--	--	--	.70	.80	
B. retrovertans	--	--	--	--	--	--	
B. saurina	--	--	--	--	.10		
Caloplaca epithallina	.25	--	--	--	--	--	
C. trachyphylla	.50	.75	.20	.80	.95	.85	
Candelariella rosulans	.45	.90	.90	.90	.95	.90	
Collema sp.	--	--	--	.10	.05	--	
Dermatocarpon miniatum	--	.10	--	.10	.10	--	
Lecanora alphoplaca	.05	--	.05	--	--	.15	
L. caesiocinerea	.95	.45	1.00	.85	.85	.75	
L. calcarea	--	.05	.10	--	--	--	
L. chrysoleuca	--	--	--	--	--	--	
L. frustulosa	.45	--	--	--	.10	--	
L. garovaglii	.90	--	.15	.10	.10	--	
L. melanothalma	.05	--	--	--	--	--	
L. muralis	.05	.05	.15	.15	--	.25	
L. mutabilis	.70	.35	.60	.85	.95	.45	
L. novomexicana	.70	--	.20	.20	.70	--	
L. peltata	.15	.25	.50	.35	.30	.25	
Lecidia auriculata	--	.50	.35	.30	.40	.65	
L. globifera	--	--	.05	--	--	--	
L. novomexicana	--	--	--	.10	.05	--	
L. plana	.20	.25	.45	.10	.05	--	
L. russellii	--	.05	--	--	--	--	
L. stigmata	.15	.55	--	.20	.70	.50	
L. tesselata	--	--	--	--	--	--	
Parmelia substygia	.25	--	--	--	--	--	
Physica sp.	--	--	--	--	--	--	
Rhizocarpon disporum	.25	--	--	--	.20	.05	
Sarcogyne privigna	.05	.05	.20	--	--	--	
Staurothele rufa	.30	.10	.85	.90	.35	.20	

*Photo plot only

Table 3.4.-30. (Continued) Frequency of all lichen species encountered along the NW transects.

Species	Stands 1	2	3	4	5	6	7
Acarospora strigata	.95	.85	.70	.60	.85	.85	.95
A. chlorophana	--	--	--	--	--	--	--
A. glaucocarpa	.05	.15	--	--	--	.25	.05
A. schleicheri	--	--	--	.05	--	--	--
A. smaragdula	.45	.40	.45	.30	.70	.50	--
Buellia punctata	--	--	--	.40	.15	--	.15
B. retrovertans	--	--	--	--	--	.05	--
B. saurina	--	--	--	--	.10	--	--
Caloplaca epithallina	--	--	--	.05	--	--	--
C. trachyphylla	.50	.10	.10	.55	.50	.45	.25
Candelariella rosulans	.70	.95	.70	.60	.35	.70	.50
Collema sp.	--	.05	.05	.10	--	--	.05
Dermatocarpon miniatum	--	--	--	.10	.10	--	--
Lecanora alphoplaca	.35	--	.05	.35	.40	--	--
L. caesiocinerea	.20	.50	--	.65	.60	.80	.75
L. calcarea	.10	.20	.20	.35	.15	--	--
L. chrysoleuca	--	--	--	--	--	--	--
L. frustulosa	.05	.20	.10	--	.55	--	.10
L. garovaglii	.15	.15	.15	.20	.15	.10	--
L. melanothalma	.10	--	.05	.10	.05	.30	--
L. muralis	.25	.15	.15	.10	.40	.25	.45
L. mutabilis	.05	.45	.80	.75	.35	.50	.85
L. novomexicana	--	.15	.05	.10	.40	--	--
L. peltata	.40	.25	.25	.55	.55	.55	.70
Lecidia auriculata	--	--	--	.05	.10	.10	.05
L. globifera	--	--	--	--	.05	--	--
L. novomexicana	--	--	--	.10	--	--	--
L. plana	--	.10	.30	.20	--	.25	--
L. russellii	--	--	--	--	.05	--	--
L. stigmata	.45	.45	.70	.15	.20	.45	.25
L. tesselata	--	--	.05	--	--	--	--
Parmelia substygia	--	--	--	.05	.15	--	--
Physica sp.	--	--	--	--	--	--	--
Rhizocarpon disporum	.05	--	--	--	.35	.15	--
Sarcogyne privigna	--	--	--	--	--	.50	.30
Staurothele rufa	1.0	1.0	.60	.30	.90	.60	.85

Table 3.4-30. (Continued). Frequency of all lichen species encountered along the NE transects.

Species	Stands 1	2	3	4	5	6 *	7 *
Acarospora strigata	.80	.85	.90	.95	.65		
A. chlorophora	--	--	--	--	--		
A. glaucocarpa	.10	.20	.25	.25	.05		
A. schleicheri	--	.05	--	--	--		
A. smaragdula	.20	.35	.45	.50	.55		
Buellia punctata	.55	.60	--	.20	.50		
B. retrovertans	--	--	--	--	--		
B. saurina	.10	--	--	.20	.05		
Caloplaca epithallina	--	--	--	--	--		
C. trachyphylla	.70	.80	.55	.75	.90		
Candelariella roseolans	.85	.95	.90	.70	.95		
Collema sp.	.10	.10	--	--	.10		
Dermatocarpon miniatum	.40	.10	--	--	.50		
Lecanora alphoplaca	--	.15	.20	--	.20		
L. caesiocinerea	.35	.70	.80	.70	.80		
L. calcarea	--	--	.10	--	--		
L. chrysoleuca	.05	--	--	--	--		
L. frustulosa	.05	.05	.05	.05	--		
L. garovaglii	.05	--	--	.45	.05		
L. melanothalma	--	--	--	--	--		
L. muralis	.05	.05	.15	.15	.35		
L. mutabilis	.40	.70	.75	.70	.80		
L. novomexicana	--	--	.40	--	--		
L. peltata	.55	.15	.45	.35	.65		
Lecidia auriculata	.45	.35	.05	.25	.55		
L. globifera	.05	--	--	--	--		
L. novomexicana	.10	--	.10	--	.05		
L. plana	.25	.25	.70	.15	.25		
L. russellii	--	--	--	--	--		
L. stigmata	.50	.35	.35	.50	.65		
L. tessellata	--	--	--	--	--		
Parmelia substygia	--	.10	--	--	--		
Physica sp.	.05	--	--	--	--		
Rhizocarpon disporum	.30	.05	--	.10	.30		
Sarcogyne privigna	.25	.10	--	.30	--		
Staurothele rufa	.75	.85	.95	.90	.80		

*Photo plot only

other parameters measured.

The total cryptogamic cover was broken down into the amount attributable to lichens and the amount attributable to mosses. Without exception, the contribution of mosses to the total cover was less than 5%. The frequency values for all other lichen species encountered is presented in Table 3.4-30.

A common method of evaluating air pollution damage to lichen communities is by determining the species richness or number of different species encountered at a site. The species list presented in Table 3.4-30 requires some qualification. Under conditions typical of cool deserts such as seasonal and diurnal temperature fluctuations, sporadic precipitation of less than 10 inches annually, and low vegetative cover, the unique morphological characteristics of many lichen species are lost. Weathered thalli of some species becomes impossible to distinguish from another species and many species due to harsh conditions infrequently produce fruiting structures, which is almost always essential for proper identification. The species listed in Table 3.4-30 are representative of those lichen species distinguishable in the field. In some instances, the vegetative thallus was present, but due to weathering it was unidentifiable and, therefore, not reported. The reliability of the information given in Table 3.4-30 is dependent upon the experience and familiarity field personnel have with desert lichen flora and some of the variation to be expected.

At each stand, three substrate samples and three samples of the lichen *L. peltata* were collected and returned to the laboratory where they were prepared and analyzed for sulfur and fluorine. Analysis for sulfur was conducted

using a LECO carbon sulfur analyzer equipped with an ignitor for hyrdocarbons. Approximately 0.5 grams of the substrate and 0.25 grams of the lichen tissue from each site were used for the sulfur analysis. Fluorine analysis included the use of the Bechman expanded scale pH meter, model number SS1 with a fluorine selective ion electrode. One gram of the lichen tissue after dry ashing and .25 grams of the substrate were used in the analysis of each sample. Each sample was fused with $Na_2O_x/NaCo_3$, dissolved with deionized water and brought to volume and analyzed by the method of known addition. The average of the three samples and the standard deviation of the elemental analyses are given in Table 3.4-29. A correlation was run to evaluate the relationship of elemental content and distance from the proposed processing site. A correlation coefficient of .0817 was achieved for sulfur content and .0128 was obtained for fluorine. Both are obviously non significant. Of the 2 elements, sample sulfur showed the least variation both between samples and within samples. The variation experienced with the fluorine samples negates or at least hinders the replicability and statistical accuracy within the time frame of the project. The elemental content values for the lichen thallus are within the range reported from similar studies by Erdman and Gough (1977) and Gough & Erdman (1977) using the terricolous lichen Parmelia chlorochroa in the vicinity of the Dave Johnston Power Plant near Glenrock, Wyoming. They reported between 360 and 1200 ppm of sulfur in the thallus of the lichen. Anderson (1983) in a similar study conducted in 1982 at the Dave Johnston Power Plant and The Laramie River Power Plant near Wheatland, Wyoming reported 480 ppm and 491 ppm/respectively, for the sulfur con-

tent of the thallus of P. chlorochroa.

Results of the 1982 studies on the use of saxicolous lichen communities to monitor air quality suggest a few minor alterations to the existing environmental monitoring manual and to the original project design. The adequacy of the current sampling procedures was evaluated by determining a minimum number of samples required to estimate total lichen and moss cover, number of species/quadrat, and lichen thallus content of sulfur and flourine. This was accomplished by using the formula $N_{min} = t^2 \frac{(s^2)}{(d\,\bar{x}\,2)}$ where t is the t-value at $\alpha = .10$, d equals 20%, s equals the sample standard deviation, $\bar{x}$ is the sample mean, and therefore, Nmin equals the needed samples size that will detect a 20% change in the mean with 90% confidence (Snedecor and Cochran, 1967). The results are reported in Table 3.4-31. The number of species/quadrat can be accurately sampled under current sampling procedures, i.e., 20 quadrats per stand. The number of quadrats necessary to adequately estimate total cover varied considerably. Stands along the NE and SE transects would require slightly less than the 20 quadrats placed. The NW transects, however, would require slightly more than 20 quadrats to adequately sample total cover at the levels deisred. Although stand comparisons may not be meaningful (statistically) quadrat comparisons will provide sufficient information on changes, if any, in total cover. The sulfur content of the lichen thallus is also sampled adequately (three samples). However, the fluorine content of the lichen thallus would require additional sampling to achieve an adequate sampling level. The expenses involved with additional elemental analysis do not justify an increase in sample size. Also, the variability

Table 3.4-31. Number of samples (quadrats) needed per stand to estimate total cover, # spp/quad, sulfur content of lichen thallus and fluorine content of lichen thallus within 20% of the mean at a 90% confidence level.

		Variable			
Transect	Stand	Total Cover	# Spp/Quad	Sulfur Content Lichen Thallus	Fluorine Content Lichen Thallus
Northwest	1	33.6	5.2	< 0.1	1.8
	2	35.1	8.3	< 0.1	7.5
	3	22.2	6.1	0.3	1.4
	4	25.7	7.8	0.1	4.8
	5	37.9	6.6	0.2	4.2
	6	35.1	11.5	0.2	6.7
	7	24.6	3.6	7.5	90.0
Northeast	1	20.0	5.0	0.5	87.8
	2	11.3	5.2	0.7	1.4
	3	17.0	3.4	2.3	4.8
	4	8.2	4.1	0.3	2.7
	5	8.7	1.0	0.5	6.8
	6	--	--	0.1	2.7
	7	--	--	< 0.1	0.2
Southeast	1	9.6	2.0	2.3	2.9
	2	10.7	4.5	0.5	8.6
	3	16.8	3.1	0.1	16.9
	4	15.9	4.5	0.3	3.3
	5	4.8	1.5	2.0	0
	6	11.2	2.3	< 0.1	8.3
	7	--	--	0.2	0

experienced with the fluorine samples suggests that additional sampling may not increase the reliability of the data. It is recommended that fluorine analysis be discontinued in subsequent years.

Parameters found to be good indicators of current conditions and valuable for monitoring future impacts include total cryptogamic cover (primarily lichen), number of species/quadrat and sulfur of lichen tissue. A minor adjustment will be made in future field evaluations for determining the frequency of all species encountered, a portion of them will be selected for monitoring in future years. The species selected will be those easily distinguished in the field and not vulnerable to weathering. The list will be as comprehensive as possible since the response of all species to potential increases in certain air pollutant concentrations is not known. It is important to include the maximum feasible number of species since they are all potential indicators of air pollution effects.

3.4.7 Plant Condition and Stress

One means of monitoring manifestations of damage due to causal agents is to regularly inspect individual plants. However, this technique is generally impractical for surveys of large areas where accessibility is limited and vegetation is rather sparse. Its use is generally restricted to small areas where the location or frequency of adverse effects is certain. Permanent plots are usually associated with this approach to monitoring. The relative complexity of the vegetation on the oil shale tracts, the large area to be surveyed, and general inaccessibility of some areas, limits the value of this approach for monitoring vegetation condition/stress on lands assoc-

iated with the White River Shale Project. Alternatively, effective monitoring can be achieved by remote sensing using color infrared (CIR) photography. Color and color infrared aerial photographs have proved to be more reliable and accurate sensors for detecting change in vegetation than black-and-white films or ocular estimates (Heller, 1978). The photographs offer a permanent record which can be used as baseline data and can be subsequently checked with new photography at a future date. In many cases, a survey can be made of comparable accuracy with less money, less time and with fewer people than by conventional ground survey methods (Wert and Rottgering, 1968).

The use of CIR photography as an aid to monitoring vegetation damage is based on the fact that physiological changes reveal themselves photographically through changes in spectral reflectance. Changes in spectral reflectance may first occur at wavelengths beyond detection with the human eye or normal color film. By the use of color infrared film, these previsual or extra-visual symptoms can be detected and recorded. Healthy vegetation regardless of vegetation type or species, usually appears a reddish color on CIR film positives or prints. Stressed vegetation grades with intensity of stress to magenta, purple, green and yellow as the loss of infrared relectance progresses. It is, therefore, the deviation relative to the appearance of healthy vegetation that becomes important in detecting vegetation stress.

Vegetative cover on portions of oil shale tracts Ua & Ub was photographed from a fixed-wing aircraft on July 19, 1982. This date coincides with the maximum stress period as determined by the phenological stage of annual plant species such as cheatgrass, halogeton and Russian thistle. The maximum stress

period was somewhat later than anticipated in 1982, due to increased late spring and early summer precipitation and lower average temperatures.

Photographic specifications followed those detailed in the Environmental Monitoring Manual (EMM). The sequence of photographs, taken at predetermined altitudes, constitute a transect that documents the condition of vegetation along that portion of the study area. Two such transects were flown within the study area (Figure 3.4-6). Both traverse the proposed plant site in Sec. 22 (T.10S, R.24E.). The first of these transects was centered along the pathway of maximum plume effluent discharge from the proposed retort in a NW-SE direction. For scale comparison purposes, it was flown at two altitudes, 600 feet above ground level, resulting in an image scale ratio of approximately 1:2,400 and 2600 feet, a scale of 1:6000. The transects are approximately 0.5 miles wide and 8 miles long (the area covered by the 1:6000 scale transect is slightly greater).

The second transect is oriented at approximately right angles to the first transect, a NE-SW direction. It is at a scale ratio of 1:2,400 and is expected to receive minimal or no gaseous discharge levels. Both transects traverse all 4 vegetation types which are delineated in the baseline report.

Ground reconnaissance was preceeded by an assessment of each CIR photograph for stressed vegetation. Vegetation showing stress as depicted by deviation from high infrared reflectance (a reddish color) was clearly marked. Once a preliminary assessment was made, the photographs were taken to the field where stressed areas were visited, and data taken as to the causal factor and frequency of the stress. Color photographs and plant voucher or

causal agent specimens were taken when appropriate for stress documentation.

During the ground reconnaissance of the stressed areas a coding system was developed in which each stressed area or individual plant was identified as to aerial photograph number, color photograph number, vegetation type, causal factor, if detectable, and the species affected.

The results of the ground reconnaissance are presented in Table 3.4-32. Photo numbers, both color and CIR, are referenced to photograph files maintained at Native Plants, Inc. for the WRSOC. Vegetation types reported corresponds to previous vegetation type delineations. All four vegetation types, i.e., juniper, sage-greasewood, shadscale and riparian, although covered by each transect, may not have been included in the ground reconnaisance.

The areas delineated as stressed can be categorized at this point into two major groups: those resulting from a phenological stage and those showing a causal agent, such as disease or mechanical disturbance. The first group is typified by annual plants such as cheatgrass, halogeton, or Russian thistle, that have set seed and have, at the time of the aerial photography, ceased growing (Figure 3.4-7). This group also includes various shrub species whose growth occurs during the cool season and by late summer are somewhat scenescent, (horsebrush, hopsage); Figure 3.4-8.

The low infrared reflectance in the second group indicates a permanent rathern than seasonal situation. It is this type of damage that is to be documented prior to the start of plant operations. Several of the dominant

Table 3.4-32. Location and characterization of stressed vegetation along two linear transects within the White River Shale project area.

CIR Photo Id.	Color Photo Id.	Veg. Type	Transect	Species	Comments
12-6-82	2-23	Juniper	SE	Pinon	Insect damage
	2-26, 28	Juniper	SE	Annuals/shrubs	Dry cheatgrass/ Russian thistle
	2-29, 32, 36	Juniper	SE	Pinon	Insect damage
	2-37	Juniper	SE	Juniper	Diseased-fungal infection
	2-38	Juniper	SE	Juniper	Decadent-cause undetectable
12-18-82	3-20	Shadscale	SE	Halogeton/ Russian thistle	Dry
12-20-82	3-21, 22	Shadscale	SE	Cheatgrass	Dry
12-20-82	3-24	Shadscale	SE	Shrub / Juniper/ Cheatgrass	Dry, sparsely vegetated
11-5-82	0-17	Juniper	SE	Juniper	Insect damage
11-9-82	0-39, 40	Sagebrush-Greasewood	SE	Shrubs	Senescent
11-20-82	3-14, 15, 16	Shadscale	SE	Annuals/Shrubs	Dry/Senescent
11-20-82	3-18, 19	Shadscale	SE	Annuals/Shrubs	Dry/Senescent
11-22-82	3-12, 13	Shadscale	SE	Annuals	Dry cheatgrass
10-18-82	3-30, 31, 32	Riparian	NE	Shrubs	Dead tamarisk
	3-33	Shadscale	NE	Annuals	Dry halogeton
9-14-82	1-20	Sage-Greasewood	NE	Shrubs	Horsebrush
	0-25		NE	Annuals	Dry Russian thistle
9-5-82	1-18, 19	Sage-Greasewood	NE	Juniper	Decadent - cause undetectable
9-7-82	1-16, 17	Sage-Greasewood	NE	Juniper	Diseased - fungal infection

Table 3.4-32 (Continued).

CIR Photo Id.	Color Photo Id.	Veg. Type	Transect	Species	Comments
8-10-82	2-12, 13, 14, 15, 16	Juniper	SW	Juniper	Diseased - fungal infection
8-10-82	2-17	Juniper	SW	Shrubs	Dry serviceberry
8-10-82	2-18, 19	Juniper	SW	Shrubs/Annuals	Horsebrush/cheatgrass
7-5-82	3-1, 3, 4	Juniper	SW	Juniper	Diseased - fungal infection
7-4	3-7, 8	Juniper	SW	Juniper	Decadent - cause undetectable
7-10	2-20, 21	Sage-Greasewood	SW	Shrubs/Annuals	Greasewood/cheatgrass
7-10	2-22	Sage-Greasewood	SW	Reseeded	Dry halogeton and cheatgrass
7-15-82	2-2	Juniper	SW	Juniper	Decadent - cause undetectable
	2-3	Juniper	SW	Juniper	Decadent - cause undetectable
	2-4	Juniper	SW	Shrub	Serviceberry - dry
	2-5	Juniper	SW	Juniper	Decadent - cause undetectable
	2-7, 8	Sage-Greasewood	SW	Annuals	Dry Russian thistle
	2-9	Sage-Greasewood	SW	Shrubs	Rabbitbrush
	2-10	Sage-Greasewood	SW	Shrubs	Rabbitbrush/ Greasewood
	2-11	Sage-Greasewood	SW	Shrubs	Serviceberry
7-18-82	1-30	Juniper	SW	Shrubs/grasses	Hosebrush/cheatgrass
	1-32, 33	Juniper	SW	Juniper	Diseased - cause unknown
	1-31	Juniper	SW	Juniper/shrubs	Serviceberry
7-20-82	1-29	Juniper	SW	Juniper	Decadent
	1-27	Juniper	SW	Juniper	Decadent
7-22-82	1-26	Juniper	SW	Juniper	Decadent
	1-25	Juniper	SW	Juniper	Portion decadent cause unknown

Table 3.4-32 (Continued)

CIR Photo Id.	Color Photo Id.	Veg. Type	Transect	Species	Comments
7-22-82	1-28	Juniper	SW	Grass	Needlegrass - dry
	1-24	Juniper	SW	Juniper	Decadent - cause unknown
	1-22	Juniper	SW	Juniper	Decadent - cause unknown
	1-21	Juniper	SW	Juniper	Diseased - cause unknown
6-22-82	0-29, 30	Shadscale	NW	Shrubs/grasses	Shadscale/rabbit-brush/greasewood/cheatgrass
5-11-82	3-5	Juniper	NW	Juniper	Diseased-cause unknown
	3-6	Juniper	NW	Juniper	Diseased - cause unknown

Figure 3.4 -7 Areas of dry halogeton along gas pipeline.

Figure 3.4 -8. Horsebush (silvery-gray appearing shrub) at time of aerial photography was dormant and showed little CIR reflectance.

tree species on the oil shale tracts show a high infrared reflectance on the July CIR photography making stressed individuals readily detectable. Stressed juniper trees were most frequently encountered as seen in Figure 3.4-9. Initial investigations show that low CIR reflectance was attributable to three major agents. Mechanical disturbance as a result of recent road and facilities construction is one cause of stressed individuals. However, this type is restricted geographically and will decrease with time. Another source of stress is old age (Figure 3.4-9-10). Many old partially decadent trees have a relatively low CIR reflectance. In many instances, the growing portion of the trees has a very high CIR reflectance (strong reddish color). The decadent portion has little to no CIR reflectance making the visual results of this particular stress factor uniquely indentifiable in CIR transparencies. The third primary causal agent is disease. Investigations this year revealed two possible disease sources. Several trees, particularly juniper trees that were partially defoliated and consequently with low CIR reflectance, showed signs of fungal infection (Figure 3.4-11). The results of another infestation, that of boring insects, was also observed (see Figure 3.4-12). Both types of infestations were detected on CIR photography (compare Figures 3.4-13 - 3.4-14 and 3.4-15 - 3.4-16), however, ground verification was necessary to detect which of the two agents were responsible.

Other species showing promise for long term monitoring are greasewood and rabbitbrush. Their robust growth in the warm season thus increased CIR reflectance, enhances their usefulness. However, neither species is easily identified or differentiated from surrounding shrubs without ground

Figure 3.4-9. Decadent tree. Compare with 3.4-10 for CIR reflectance.

Figure 3.4-10. CIR aerial photograph of juniper tree (circled) shown in 3.4-9.

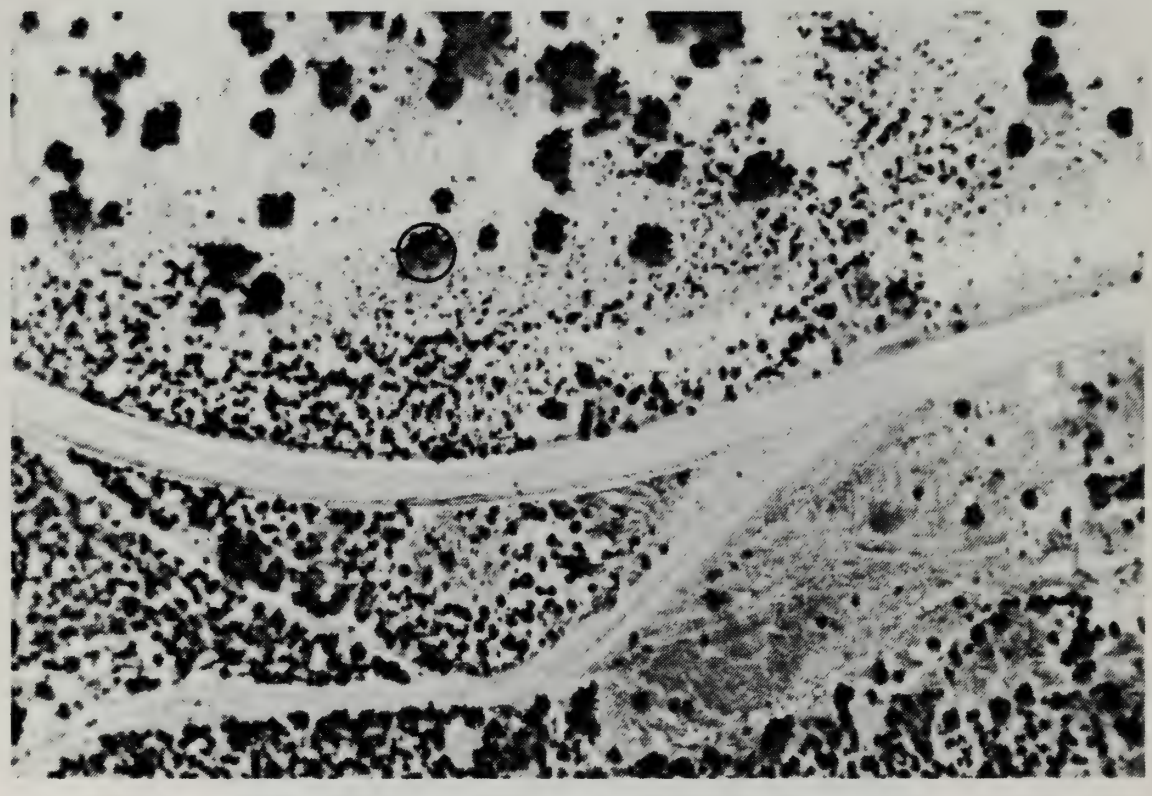


Figure 3.4 -11. Fruiting structure of fungus observed on several juniper trees. Photograph of juniper tree shown in Figure 3.4 -9 and 3.4 -10.

Figure 3.4 -12. Evidence of insect damage to a pinon tree shown in Figure 3.4-15 and 3.4 -16.

Figure 3.4-13. Dead juniper tree. Compare with Figure 3.4-14 for respective CIR reflectance and Figure 3.4-11 for possible cause of death.

Figure 3.4-14. CIR aerial photograph of juniper tree (circled) shown in 3.4-13.

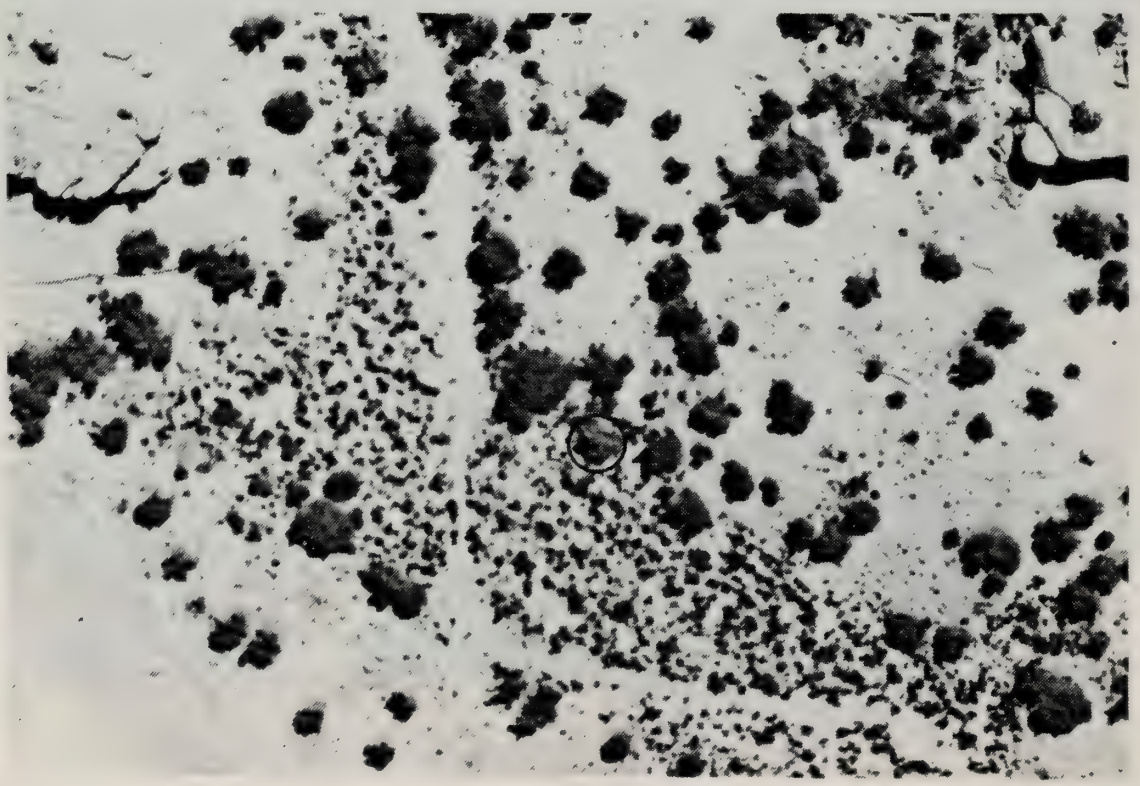
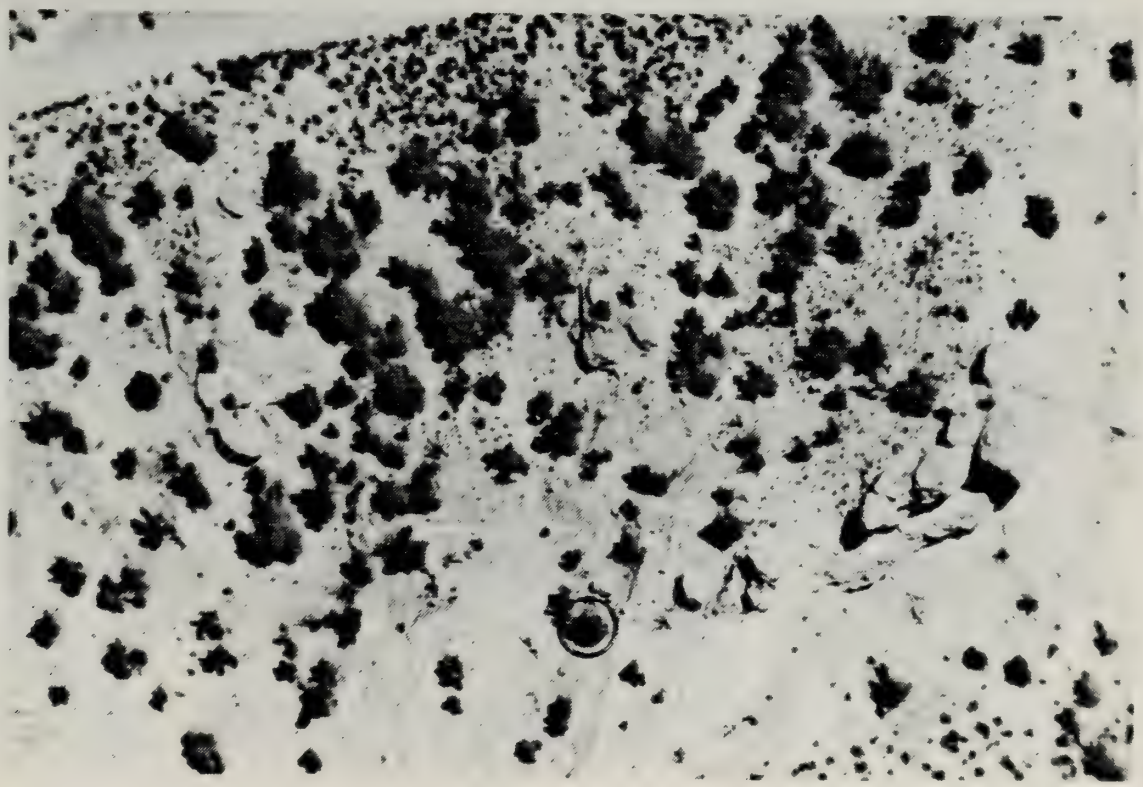


Figure 3.4-15. Dead pinon tree. Compare with Figure 3.4-16 for respective CIR reflectance and Figure 3.4-12 for possible cause of death.

Figure 3.4-16. CIR aerial photograph taken at a scale of approximately 1:2400. The tree circled is the pinon tree shown in Figure 3.4-15.



verification.

As explained in the methods section, the NW-SE transect was photographed at two scales, 1:2400 and 1:6000. The purpose was to determine the appropriate scale for future monitoring of vegetation condition. Differences between the two scales are depicted photographically in Figures 3.4-17 and 3.4-18. Figure 3.4-18 is at a scale of 1:6000 and Figure 3.4-17 at 1:2400. On the 1:6000 photograph individual juniper trees and some shrubs are distinguishable. However, examination of the positive overlays with a topcon stereoscope reveals that infrared reflectance is subdued and detection of stressed individuals is less apparent or even undistinguishable. The infrared reflectance of the 1:2400 photos is much more crisp even to the point where a portion of a tree that is stressed is detectable (Figure 3.4-19, also see Figure 3.4-20).

It is the conclusion of this years evaluations that the photography at a scale of approximately 1:2400 is most appropriate for monitoring vegetation stress on the White River Shale Oil tracts. If a more dense vegetation was present on the oil shale tracts, a scale of 1:6000 or smaller would be advantageous in showing overall vegetation stress. Also, due to the sparsely vegetated land, the use of individual plants, rather than overall vegetation types, would be most effective in monitoring vegetation changes due to stress which may result from oil shale project activities.

The results of the current years studies on the use of CIR photography to document and monitor vegetation stress has prompted a few adjustments to this section as outlined in the EMM. Monitoring manual guidelines dictate

Figure 3.4-17. CIR aerial photograph taken at a scale of approximately 1:2400. Compare with Figure 3.4-18.

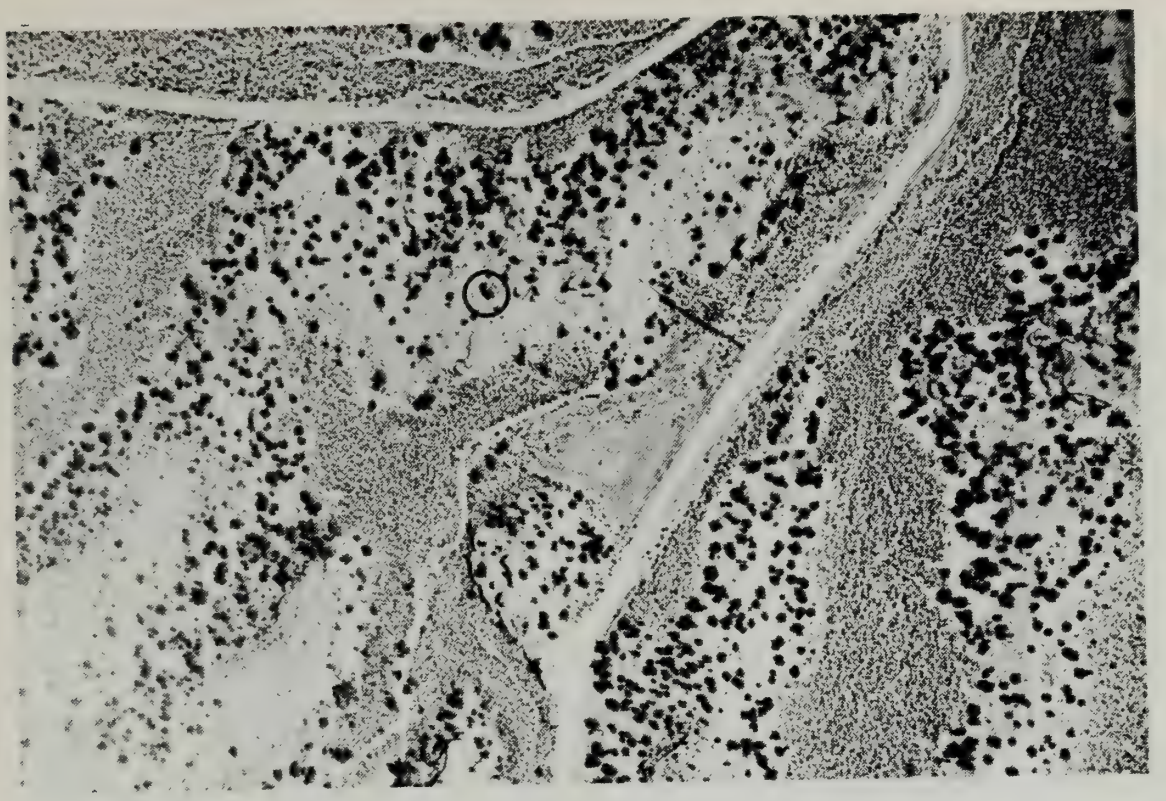


Figure 3.4-18. CIR aerial photograph taken at a scale of approximately 1:6000. Compare CIR reflectance values with Figure 3.4-17.

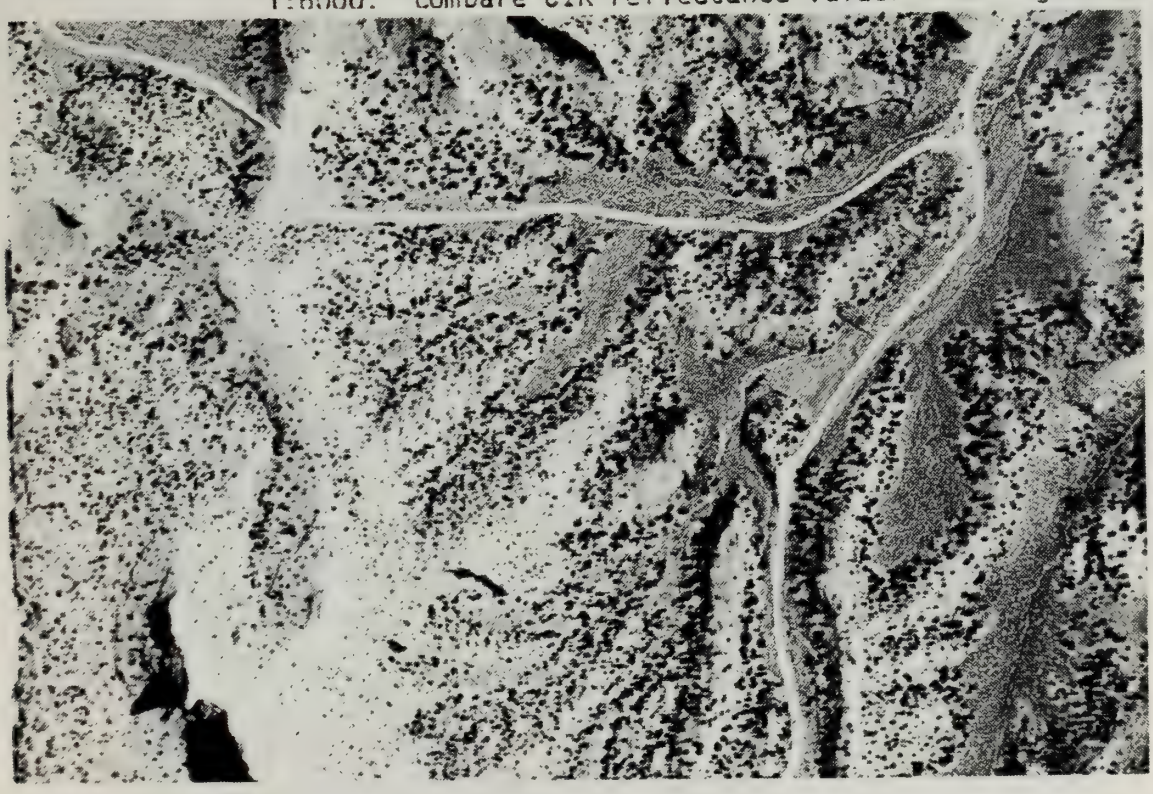


Figure 3.4-19. CIR aerial photograph of a partially dead juniper tree. Compare with Figure 3.4-20 (14)

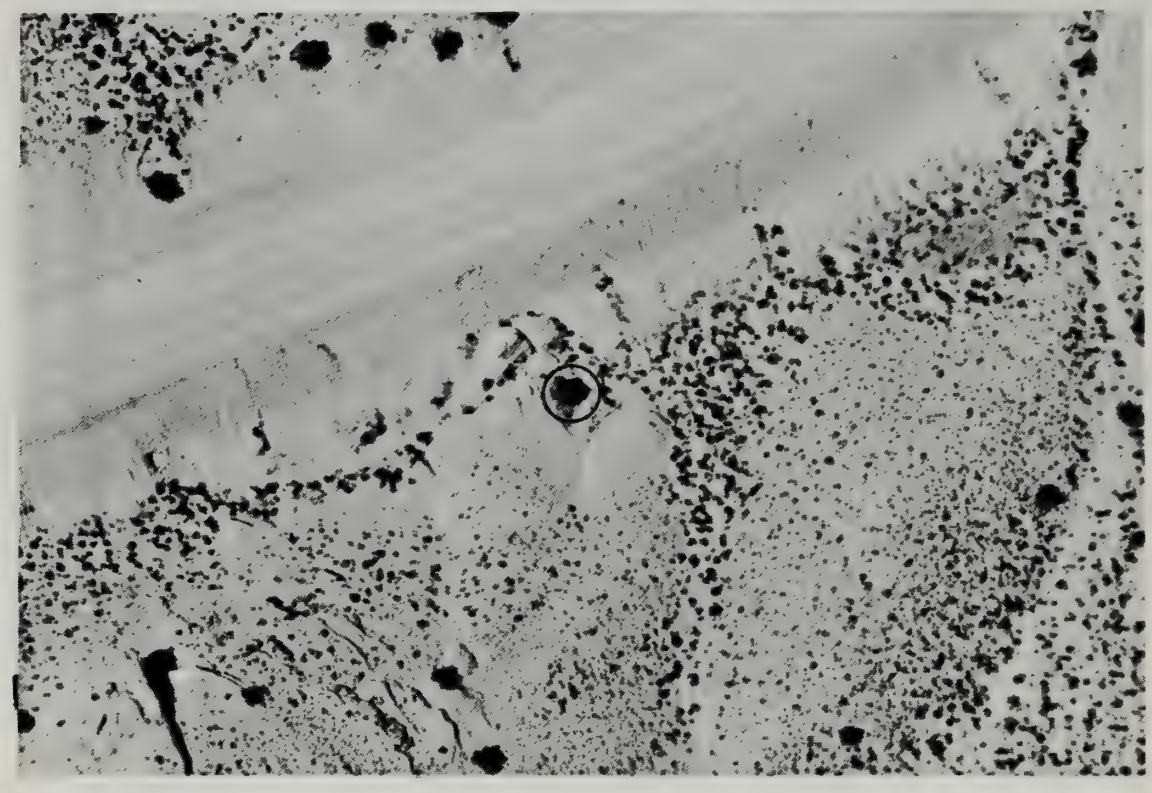
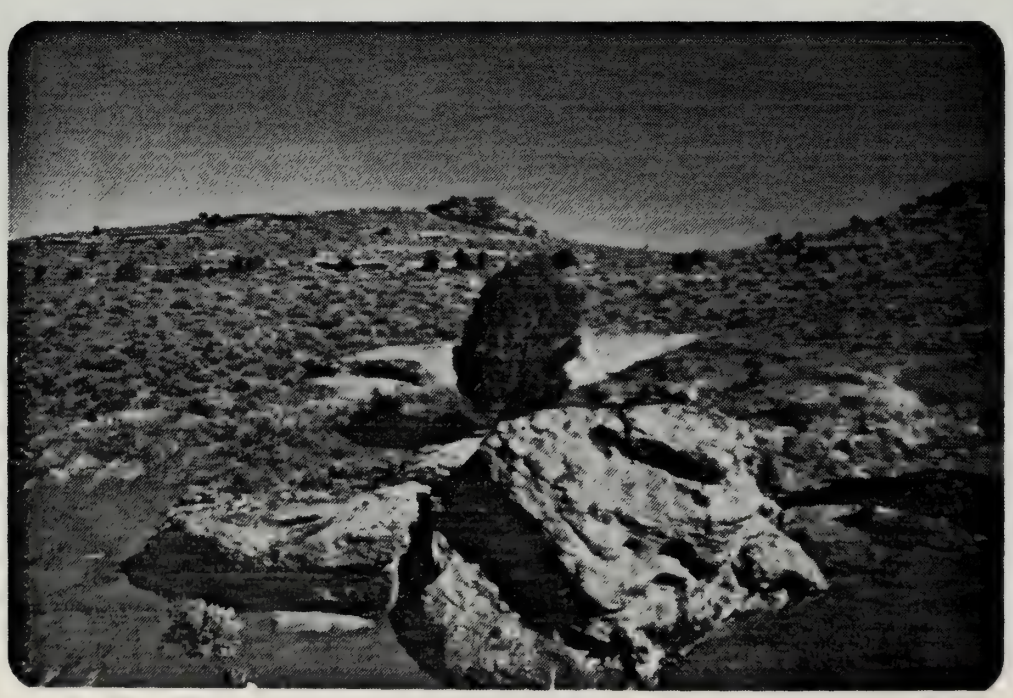


Figure 3.4-20. Partially decadent juniper tree. Compare with Figure 3.4-19 for respective CIR reflectance.



three transects to be photographed. Two at a scale of 1:2000 and one at a scale of 1:6000. The third transect was for comparative purposes and need not be photographed after year one. Two transects, one in a NW-SE direction in the direction of the maximum plume discharge from the retort will be photographed in following years. Both transects should be at a scale of approximately 1:2400.

Each transect will extend six miles from the proposed plant site in each direction. For example, the NW-SE transect would be a total length of 12 miles, six miles from the plant site in a southeasterly direction and six miles in a NW direction. The same would hold for the NE-SW transect. The 12 mile transect length would, therefore, include the transects established for lichen monitoring of air quality and facilitate correlation of the two monitoring techniques.

The initial years study on the use of CIR photography to monitor plant stress has been a qualitative evaluation of methodologies. The results, although subjective, are positive. Monitoring plant stress with CIR photography in subsequent years will include a quantification of the information presented. Stressed individuals will be counted on a per unit area basis. The quantified 1982 CIR photography will be used with the following years data to establish a standard of plant stress prior to retort plant start up.

3.4.8 Soil Microbiology and Soil Chemistry

Sampling for soil microbiology and chemistry occurred in February, April, June, August, and October, 1982 along transects at eight sites within oil shale tracts Ua and Ub (Figure 3.3-1). In August and October additional

samples were taken from site VR4 in anticipation of losing the VR2 site when the White River Dam is completed. Soils were collected as in 1981. Table 3.4-33 summarizes the 1982 sampling effort.

All samples were sieved using a 2 mm screen and analyzed for moisture content, pH, EC, organic carbon, total bacteria, total fungi, respiration, and dehydrogenase activity. Methods were identical to those described in the EMM, 1982. Measures of moisture content and microbiological analyses were performed on fresh soils within a week of collection. The pH, EC, and organic carbon assays were performed on air dried samples.

Complete sets of April and August 1982 soil samples were oven dried and heat sealed in plastic bags. These will be used as reference samples for future chemical analyses if and when impacts of oil shale development are suspected.

3.4.8.1 Soil Moisture Content Mean soil moisture content (all sites, all depths) fluctuated from a February high of 23.5 ± 10.1% to a June low of 2.2 ± 1.1% (Table 3.4-33, Figure 3.4-21). During summer months, moisture levels were generally 1-2% higher in subsurface (5-15 cm) soils than in surface soils (0-5 cm). In winter months, surface soils generally contained 5-10% more moisture than subsurface soils. There were few differences in soil moisture content between sites (Table 3.4-34). Riparian soils were generally more moist than upland soils, but due to high variability, differences were not statistically significant. These patterns closely paralleled those found in 1981, although 1982 moisture levels were generally 3-4% higher than those recorded in the previous year.

Table 3.4-33. Monthly means ($\bar{X} \pm S$) for chemical and microbiological characteristics of WRS soils. Values are averages for all transects and soil depths sampled during the given month.

Variable	Unit	February	April	June	August	October
Moisture	%	23.5 ± 10.1	9.3 ± 2.6	2.2 ± 1.1	5.7 ± 2.3	5.1 ± 1.6
pH		8.1 ± 0.3	8.2 ± 0.2	8.2 ± 0.2	8.1 ± 0.2	8.2 ± 0.2
EC	mmho/cm	0.33 ± 0.16	0.22 ± 0.08	0.27 ± 0.10	0.26 ± 0.12	0.21 ± 0.19
Organic Carbon	%	1.28 ± 0.50	1.02 ± 0.38	1.26 ± 0.45	1.04 ± 0.54	1.04 ± 0.55
Total Bacteria	10^6 CFU/g	89.0 ± 63.7	13.9 ± 7.0	2.5 ± 1.6	5.8 ± 4.3	10.5 ± 6.7
Total fungi	m hyphae/g	57 ± 30	54 ± 31	51 ± 33	37 ± 30	38 ± 24
Respiration	10^{-4} meq CO_2/g · hr	10 ± 2	4 ± 2	2 ± 1	3 ± 1	3 ± 2
Dehydrogenase	mg formazan/liter	8 ± 8	11 ± 7	19 ± 7	13 ± 7	13 ± 7

Figure 3.4-21. Monthly mean moisture contents for 0-5 cm (O) and 5-15 cm (●) soils. All sites are included. Results for 1981 and 1982 are compared.

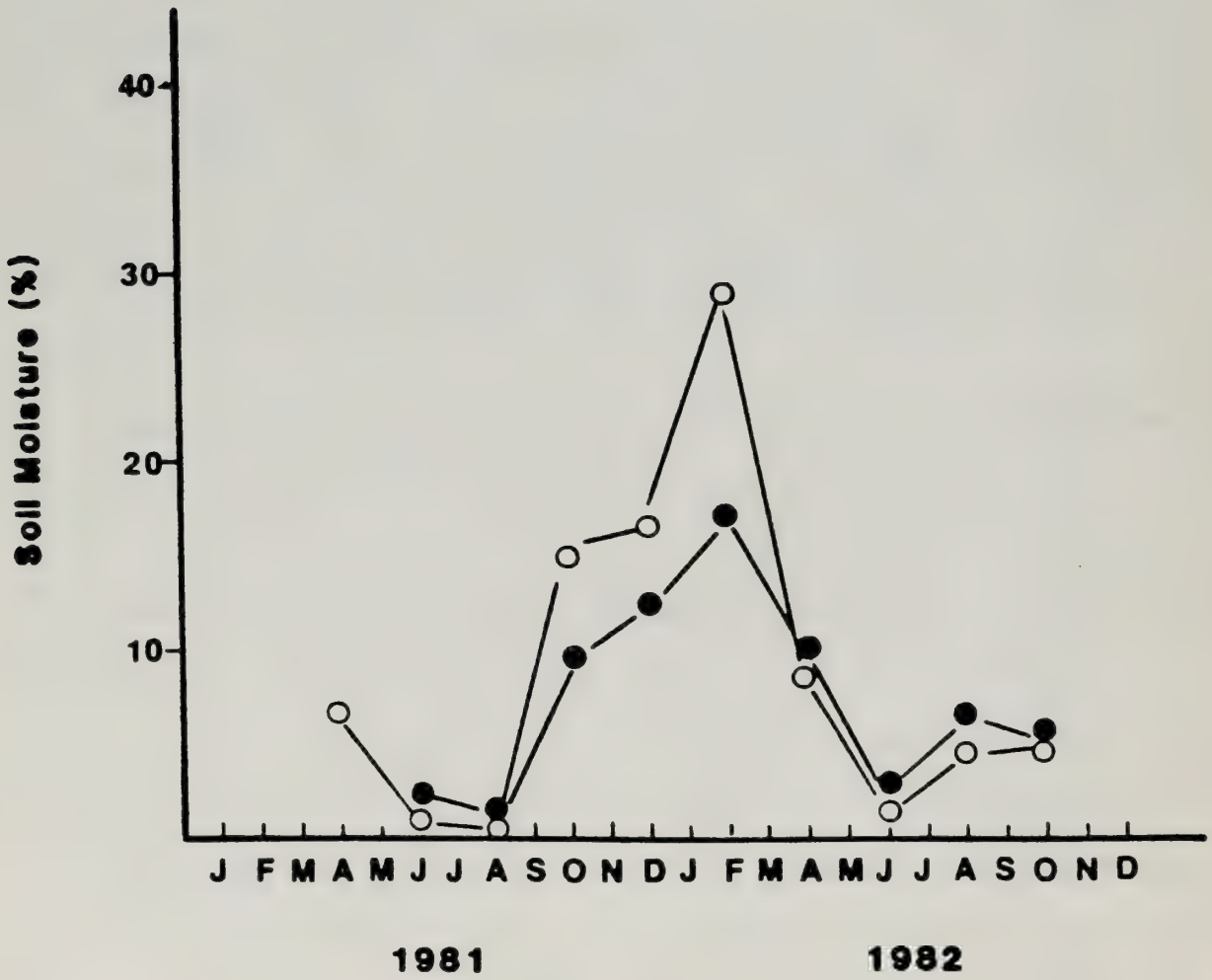


Table 3.4-34. 1982 annual means ($\bar{X} \pm S$) for chemical and microbiological characteristics of WRS soils. Values are given by transect and depth interval. *Site VR4 was sampled only in August and October.

Variable	Unit	Depth	Site								
			VS1	VS4	VG1	VG2	VG3	VJ1	VJ5	VR2	VR4*
Moisture	%	0-5	9.9±11.3	6.7±7.1	8.5±10.0	9.8±11.9	9.2±10.4	8.7±10.1	9.0±10.1	16.0±17.6	5.6±1.7
		5-15	9.9±5.9	7.7±5.1	7.5±5.2	7.8±5.0	6.6±5.0	8.3±5.5	8.3±5.0	11.0±6.3	6.3±1.4
pH		0-5	8.1±0.1	8.0±0.3	8.1±0.1	8.1±0.1	8.0±0.2	8.1±0.2	8.0±0.2	8.1±0.3	7.9±0.1
		5-15	8.3±0.2	8.4±0.2	8.3±0.2	8.3±0.2	8.4±0.3	8.2±0.3	8.3±0.3	8.3±0.2	8.1±0.2
EC	mmho/cm	0-5	0.30±0.08	0.24±0.10	0.20±0.10	0.22±0.06	0.29±0.08	0.21±0.10	0.26±0.19	0.36±0.12	0.56±0.28
		5-15	0.26±0.08	0.25±0.14	0.20±0.12	0.18±0.08	0.20±0.04	0.19±0.08	0.26±0.19	0.25±0.07	0.46±0.31
Organic Carbon	%	0-5	1.84±0.45	1.03±0.33	1.12±0.39	1.07±0.30	1.16±0.42	1.27±0.40	1.39±0.29	1.19±0.53	2.45±0.69
		5-15	1.41±0.39	0.94±0.43	0.79±0.33	0.79±0.23	0.72±0.24	0.88±0.20	1.10±0.48	0.93±0.30	1.18±0.25
Total Bacteria	10^6CFU/g	0-5	27.7±47.7	22.4±34.5	23.9±35.3	41.4±94.8	30.7±49.0	33.7±59.6	11.6±16.1	67.4±115.3	13.2±11.7
		5-15	16.3±21.3	11.1±13.5	15.7±17.5	17.6±22.8	14.9±21.2	8.7±10.4	19.2±44.6	23.9±20.3	7.5±2.4
Total fungi	m hyphae/g	0-5	49±24	43±22	29±16	33±19	32±23	52±20	42±21	43±26	40±18
		5-15	74±38	81±39	33±22	48±25	18±10	76±32	71±38	27±8	49±29
Respiration	10^{-4} meq CO_2/g ·hr	0-5	6±4	4±4	4±4	4±5	5±4	5±4	4±3	6±4	3±1
		5-15	5±2	4±2	3±3	4±2	3±3	4±4	4±2	5±3	3±2
Dehydrogenase	mg formazan/liter	0-5	22±8	16±7	16±7	17±6	18±6	13±6	19±5	15±12	17±6
		5-15	12±7	9±6	8±5	8±5	7±4	8±4	10±5	6±6	4±1

3.4.8.2 pH and EC Soil pH's averaged 8.0 ± 0.2 in the 0-5 cm zones and 8.3 ± 0.2 in the 5-15 cm zones of soils on tract. (These values are geometric means for all 1982 samples). The slightly lower values of the surface soils may reflect their higher organic matter contents. There were no significant differences in soil pH between transects or sampling dates (Tables 3.4-33, 34). These results are identical to those measured in 1981.

Electrical conductivities of the soils sampled averaged 0.26 ± 0.14 mmhos/cm (all transects, depths, and dates). There were no significant differences in EC between sampling dates or sample depths (Table 3.4-33, 34). Soils from the two riparian sites (VR2 and VR4) had the highest EC's, presumably reflecting salt accumulation from surface evaporation. These results are similar to those measured in 1981 with the exception that this years EC's of surface soils were, in average, 0.12 mmhos/cm (30%) lower than in the previous year. This shift was consistent across most transects and may have reflected the generally higher rainfall (and leaching of surface salts) that coincided with the 1982 sampling dates.

3.4.8.3 Organic Carbon Organic carbon contents averaged 1.32 ± 0.53% in 0-5 cm soils and 0.96 ± 0.39% in 5-15 cm soils on the White River tracts. These levels were slightly higher than those measured in 1981, but differences between years were not statistically significant. The annual trend in declining organic matter that was noticed last year did not appear this year (Table 3.4-33). Variation between sites was similar, however. Again, soils from site VS1 and VR4 tended to have higher levels of organic carbon than soils collected at other sites (Table 3.4-34).

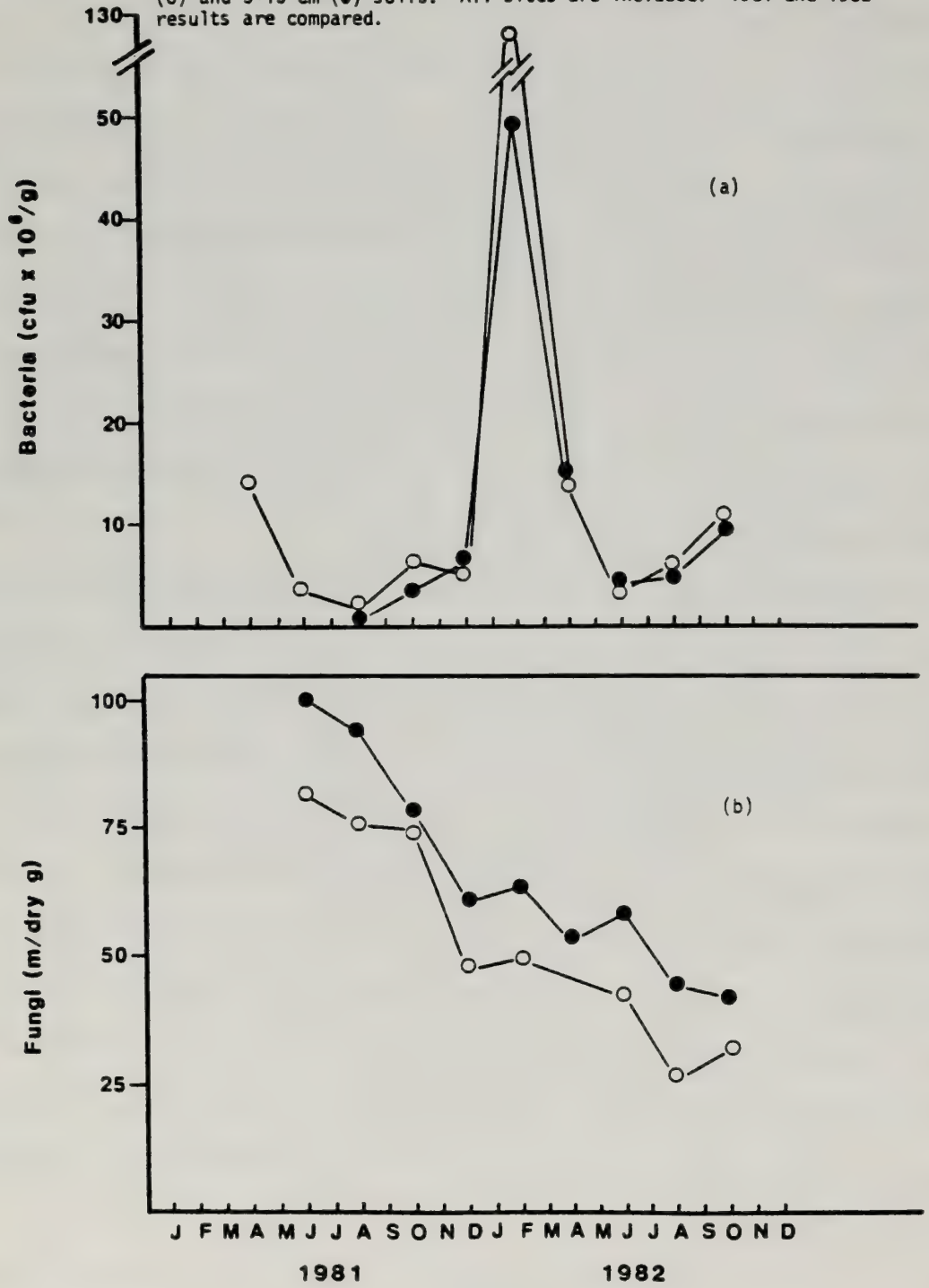
3.4.8.4 Total Fungi Bacteria Soil bacteria fluctuated in an annual cycle characterized by a sharp winter peak and a summer low (Figure 3.4-22a). In 1982, counts hit a maximum of 89.0 $\pm$ 63.7 x 10^6 CFU/g (all sites, all depths) in February and a minimum of 2.5 $\pm$ 1.6 x 10^6 CFU/g in June. Spring and fall values fell in the 5-15 x 10^6 CFU/g range (Table 3.4-33). This cycle replicates nicely the values obtained for 1982 (Figure 3.4-22a). Factors governing these fluctuations will be discussed later. On the average, bacterial counts for subsurface (5-15 cm) soils were 50% lower than counts for surface (0-5 cm) soils, but this differenct was significant only for the month of February. Sample variances were high and no significant differences in bacterial populations between sites were noted.

Fungal populations on 0-5 cm soils showed a general decline from 50 m/g in February 1982 to about 30 m/g in August and October (Figure 3.4-22b). Subsurface (5-15 cm) populations behaved similarly but were consistently higher than surface populations by about 20-25%. Few differences were evident between transects, but the sagebrush (VS1 and VS4) and juniper (VJ1 and VJ5) sites supported generally high subsurface populations of fungi.

The general declines in fungal numbers with time is a trend that has continued since June 1981 when the fungal measures were initiated (Figure 3.4-22b). We suspect that this pattern is an artifact of viewer fatigue associated with the epiflourescent counting method. To test this assumption, we will run a second fungal analysis (plate count) in parallel with the direct counts during 1983.

3.4.8.5 Respiration and Dehydrogenase Activities Mean rates of respira-

Figure 3.4-22. Monthly mean total bacteria and total fungi counts for 0-5 cm (O) and 5-15 cm (●) soils. All sites are included. 1981 and 1982 results are compared.



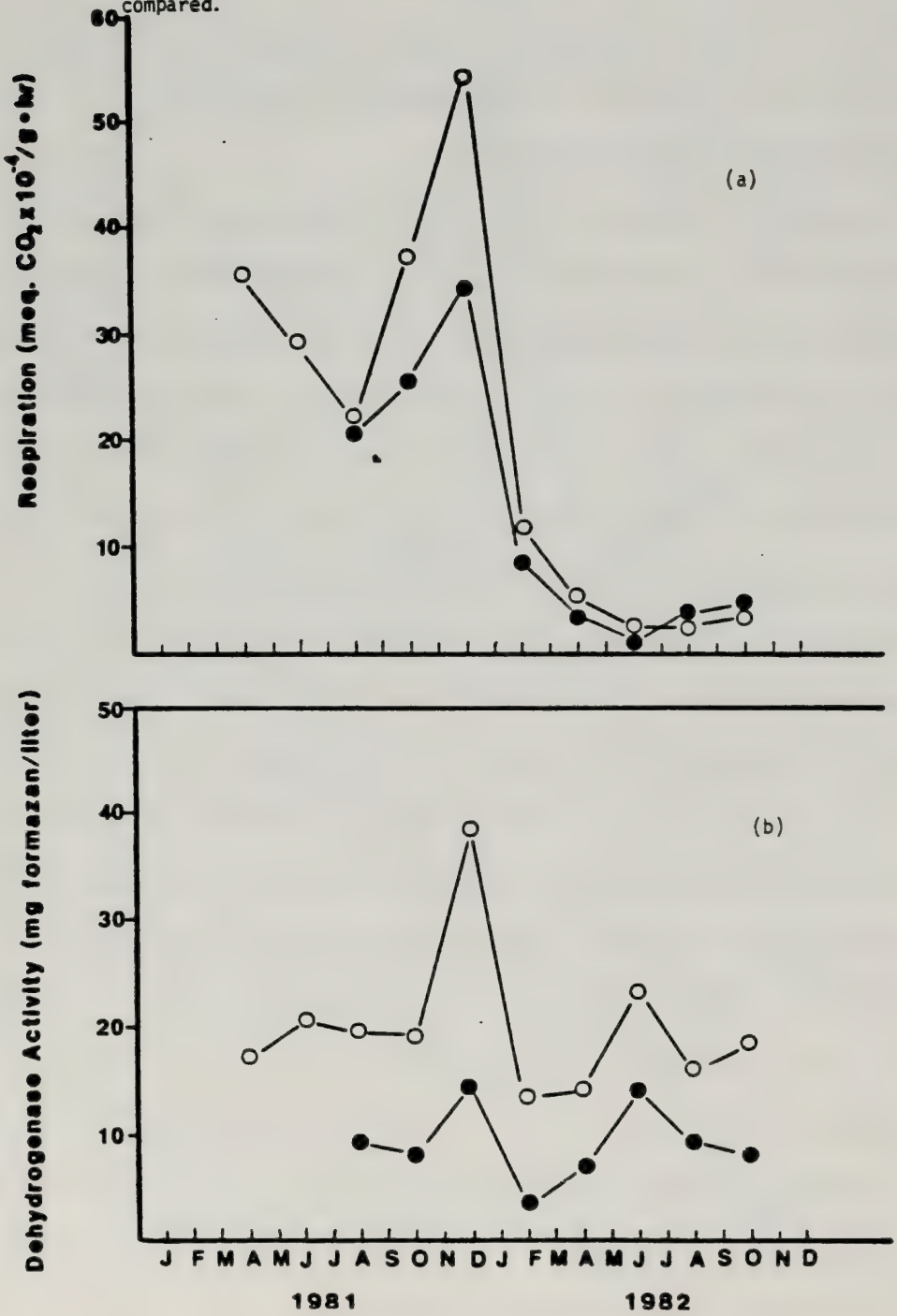
tion in surface soils showed an annual cycle characterized by a February high of 11.5 ± 1.7 meq CO_2 x 10^{-4}/g · hr. and a June low of 1.9 ± 1.8 meq CO_2 x 10^{-4}/g · hr. Subsurface soils followed a similar pattern (Table 3.4-33, Figure 3.4-23a). There were no significant differences in soil respiration between sampling depths or transects.

While respiration values for 1981 also showed an annual cycle of winter highs and summer lows, data for that year was approximately 10-fold higher in magnitude than that recorded of 1982. Respiration assays in 1981 were performed by a laboratory at USU. Techniques were similar to those used this year, but we have subsequently learned that samples were typically stored for 4-6 weeks prior to analysis. We suspect this "incubation" period may account for the high respiration results recorded for 1981.

Dehydrogenase activities in the soil sampled showed an annual cycle in 1982 that was opposite in timing to those of most other characteristics. Mean values (all transects, all depths) hit a minimum in February of 8 ± 8 mg formazan/liter and a maximum in June of 19±7 mg formazan/liter (Table 3.4-33). Soils from the two depth intervals behaved similarly, although surface materials consistently showed almost twice the dehydrogenase activity of subsurface materials (Figure 3.4-23b). There were no consistent differences between transects for this parameter (Table 3.4-34).

Dehydrogenase activities for 1981 and 1982 were similar in magnitude, but annual patterns differed between years (Figure 3.4-23). In 1981 the annual high was reached in December. Continued sampling should reveal the presence or absence of repeating annual cycles.

Figure 3.4-23 Monthly mean respiration and dehydrogenase activities for 0-5 cm (O) and 5-15 cm (O) soils. All sites are included. 1981 and 1982 results are compared.



3.4.8.6 Correlation between chemical and microbiological factors

Correlation coefficients linking the eight variables measured for White River soils are given in Table 3.4-35. This analysis includes all samples collected during 1982. Only relationships for which $\alpha \leq 0.01$ are listed.

Correlation coefficients among chemical parameters mirror the relationships found in 1981. Again, the finer textured soils, with generally higher moisture contents, tended to have lower pH's, higher EC's and higher organic carbon contents (see 1981 final report).

Coefficients linking chemical and microbiological properties showed the following:

1. As expected, high bacterial counts and microbial respiration levels were associated with relatively moist soils. Water stress typically limits microbial growth activity in arid areas (Knight, 1978). Dehydrogenase activity, however, showed the opposite relationship.
2. Bacterial numbers and activities tend to be positively correlated with organic matter content and negatively correlated with pH. That is, the more acid soils, rich in organic matter, tend to support larger and more active microbial populations. Again, this result is expected. Soil organic matter is the primary energy source for microbial populations and as already mentioned, soil acidity can be generated through organic matter decomposition.
3. Fungal counts were, in general, not correlated with soil chemical characteristics.

Correlations among microbiological parameters indicated a strong positive

Table 3.4-35. Correlation coefficients linking chemical and microbiological parameters measured for WRS soils. All 252 samples collected in 1982 are included in this analyses. Only relationships for which $\alpha \leq 0.01$ are listed.

	Moisture	pH	EC	Organic Carbon	Total Bacteria	Total Fungi	Respiration	Dehydrogenase
Moisture		-0.15	0.20	0.18	0.84		0.83	-0.19
pH			-0.19	-0.33	-0.22		-0.17	-0.31
EC				0.44	0.19		0.23	
Organic carbon					0.16	0.18	0.21	0.47
Total Bacteria							0.69	
Total Fungi							0.17	
Respiration								-0.22
Dehydrogenase								

relationship between bacterial counts and respiration, a weak (but significant) positive relationship between fungal counts and respiration, and a negative association between respiration and dehydrogenase.

In general, the coefficients given in Table 3.4-35 are low ($\pm$ 0.2-0.5), but this is not surprising given that all sampling periods, sites, and depth intervals are included. As in 1981, correlation coefficients for soils collected from a given depth on a given date were generally higher ($\pm$ 0.4-0.6) but the significance ratings were not different.

Most 1982 results are statistically identical in magnitude to results obtained in 1981. Repeating annual cycles in soil moisture, bacterial counts, and respiration are beginning to appear. Most parameters being measured are significantly correlated with one another, and most of the correlations make biological sense. This is evidence that a coherent package of variables have been chosen and that our measurement techniques are sound. As WRSP data is compared with those of others, it is expected that significant cause and effect relationships linking soils with vegetation and wildlife will appear.

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AQUATIC BIOLOGY

4.0. AQUATIC BIOLOGY

4.1. INTRODUCTION

An aquatic biology baseline investigation was conducted in the White River and Evacuation Creek adjacent to Tracts Ua and Ub by VTN Consolidated during the period April, 1975 through August, 1976. In this program, data was collected for fish, macroinvertebrates, periphyton, and phytoplankton. This data will be discussed in this report in relation to on-going efforts. The aquatic biology baseline program was suspended in 1976 for an interim period lasting until 1981.

In April, 1981 the aquatic biology program was reestablished in anticipation of further project development. The objectives of the 1981 program were to reestablish the baseline and begin developing an effective long-term monitoring program. These objectives are discussed in more detail in Section 4.3 Program Description. The 1981-82 aquatic biology monitoring program for WRSP was under the direction of Ecosystem Research Institute of Logan, Utah.

The 1982 program, the results of which are discussed in this report, was a continuation of 1981 efforts through August, 1982. At that time some program changes were instituted as recommended in the 1981 final report (ERI 1982). The major change was the elimination of regular sampling in Evacuation Creek and the pool transects in the White River.

In anticipation of construction of the White River Dam, which will destroy the present on-tract riffle transect (WR18) and inundate the upstream

riffle transect (WR03), a search was begun for more appropriate long-term sampling locations. One potential riffle transect was located and surveyed at Cowboy Canyon, upstream of the tracts. No downstream site was sampled.

A special study was instituted during 1982 to document the status of important metals in the White River system and their significance to the biota. The initial findings of this study are described in the final section of this report. The remaining data will be presented in quarterly reports and in the 1983 final report.

During 1982, the Environmental Monitoring Manual (EMM) for Tracts Ua and Ub was published (WRSOC 1982). This document established criteria for monitoring all disciplines, including aquatic biology. The program established in the EMM is described in greater detail in Section 4.3. One of the dominant requirements of the EMM was the establishment in all disciplines of a detailed quality control program. This program was instituted for aquatic biology during 1982 and the initial results are presented in Section 4.3. Laboratory certification procedures were begun to meet the requirements of the State of Utah Department of Health and the U. S. Environmental Protection Agency for certain chemical and biological parameters. The standards have been met and certification has been obtained.

As stated, the EMM directs the program, establishing parameters, methods, and sampling frequency. It is expected that the aquatic biology program will continue to evolve through 1983. Efforts during the coming year will be concentrated on reducing sample variability to assure better confidence for impact detection in the future. At the close of 1983,

adequate descriptive data on both structural and functional parameters will have been collected to allow further program refinement and cost savings.

4.2. SUMMARY

Completion of the 1982 Aquatic Biology Monitoring Program has resulted in greater understanding of the White River Ecosystem and the processes occurring therein. This greater understanding has led to program refinement based upon quantitative expression of the results of data collection during 1981 and 1982. Data collection and experiments designed for 1983 will have two major outputs. First, quantitative ecosystem relationships may begin to be developed. Second, innovative techniques such as P/R and leafpack decomposition should become operational parameters, as the difficulties with technique are overcome.

During 1982, the dominance of the biology of the White River by physical factors was more evident than in 1981. The impact of physical forces was accentuated by comparison of 1982 data with 1981 data. In 1982, biological production was very low when compared to 1981 which was a highly productive year.

The physical factor of overriding importance to the biology of the system was discharge. Discharge levels in 1982 were higher than in 1981. As a result, total suspended solids were higher and light penetration reduced. In addition, some transects (WR20 and WR27) were greatly modified by high upper basin runoff in the summer of 1982 while the remainder appeared stable.

The water chemistry of the river was changed as a result of the difference in hydrologic regime. Nutrients, particularly the forms of phosphorous, were altered, with 1982 levels in excess of 1981. Inorganic nitrogen did not follow the same pattern and appeared lower in 1982 with the

exception of the late July sample period which relects results of a storm in the drainage basin.

The biology of the system reflected these physical environmental factors. Benthic organic matter (CPOM) was elevated due to the discharge related allochthonous inputs of terrestrial organics from the watershed.

The periphyton biomass was lower in 1982 than in 1981. This reflected the scouring by suspended sediment and reduced light penetration. Eventhough more nutrients were available in 1982 than 1981, production of algae was lower due to these physical factors. Periphyton biomass as chlorophyll a for the three riffle transects (WR03, 18, 27) was not significantly different by ANOVA.

Macroinvertebrate species richness followed a consistent pattern during 1981 and 1982 with highest richness during the summer and lowest during winter. Transect WR27 was erratic when compared to WR03 and WR18. Patterns in 1982 appeared more variable probably due to physical habitat disruption related to discharge events.

Macroinvertebrate numbers and biomass followed a similar pattern as periphyton biomass with peaks occurring during low discharge and high light periods during 1981. This indicated that similar environmental conditions and partial dependence upon a periphytic food base were important factors. Numbers and biomass were lower during 1982 reflecting a more harsh physical environment and lowered primary production. Transect WR27 was significantly lower in numbers and biomass than WR03 and WR18 reflecting the instability of this transect.

Data collected during 1975-1976 in the baseline investigation conducted by VTN indicated that periphyton biomass as chlorophyll a occurring in riffle areas varied from a high of 37.1 mg/m^2 to 0.0 mg/m^2. Most values were lower than 2.6 mg/m^2 indicating much lower periphyton standing crops than found during 1981 and 1982 when values or transects varied from a low near 3 mg/m^2 to a high of near 115 mg/m^2.

Macroinvertebrate data collected in September, 1975 and August, 1976 indicated average densities of 1547 and 2648 individuals/m^2. Data from 1981 was comparable for the same time periods with maxima near 2700 individuals/m^2 while 1982 invertebrate density was low (approximately 100 individuals/m^2).

A more detailed synthesis of the 1975, 1976 aquatic biology baseline data awaits the completion of taxonomic verification on 1981 and 1982 periphyton and macroinvertebrate data. These results and comparisons will be presented in quarterly reports and the 1983 final report.

Decomposition rate as measured by leafpacks continued to show a consistent rate with degree days. Problems with silting and anerobic conditions which developed within the leafpacks caused a loss of some 1982 data. These problems will be corrected with technique modifications during 1983.

An investigation of the role of metals in the White River ecosystem was begun in 1982. Metal levels in the White River biota were found to be elevated above those found in the literature for other river systems except for those with high industrial pollution. The input from Evacuation Creek and proximity to oil shale and marlstones of the Green River formation are

probable leading causes.

As a result of the 1982 program, one program change appears to be necessary. Transect WR27, the downstream riffle transect, was found to be relatively unstable with a shift in channel occurring during upper basin runoff. This channel migration will continue to occur and maintain the instability of this transect. It is recommended, therefore, that a new more stable riffle transect near WR27 be located during 1983. Other anticipated program changes as a result of 1983 data collection will be refinements in technique to reduce sample variability. Future anticipated major changes will occur in conjunction with the construction of the proposed White River Dam. These will be developed for inclusion in the 1983 final report.

4.3. PROGRAM DESCRIPTION

When the aquatic biology program was reinstituted on the White River and Evacuation Creek in 1981, the program objectives were fivefold:

- To characterize the White River and Evacuation Creek habitats in order to develop the most appropriate sampling sites for monitoring.

- Gather ecosystem - level data which would be important in tracing the fate and consequences of introduced foreign substances.

- To develop appropriate techniques which can be utilized efficiently in a long-term monitoring program.

- Determine those ecosystem parameters which have the greatest importance for long-term monitoring and the assessment of impacts.

- Develop statistically significant interrelationships between aquatic and other ecosystems (as well as within the aquatic ecosystem).

These objectives provided program guidance until sufficient data was collected in order to determine the most appropriate sampling locations, parameters, and techniques for long term monitoring and assessment of impacts. This was partially accomplished during 1982 with the completion of one full year of data collection.

The Environmental Monitoring Manual (EMM) established this long-term program in its initial form. Long-term sample sites were delineated at six transects in the White River. These were riffle transects WR03, 18, 27 and pool transects WR05, 20, 29. Sampling in Evacuation Creek was discontinued because project impacts were not anticipated to occur within this stream. See Figure 4.3-1 for sample locations.

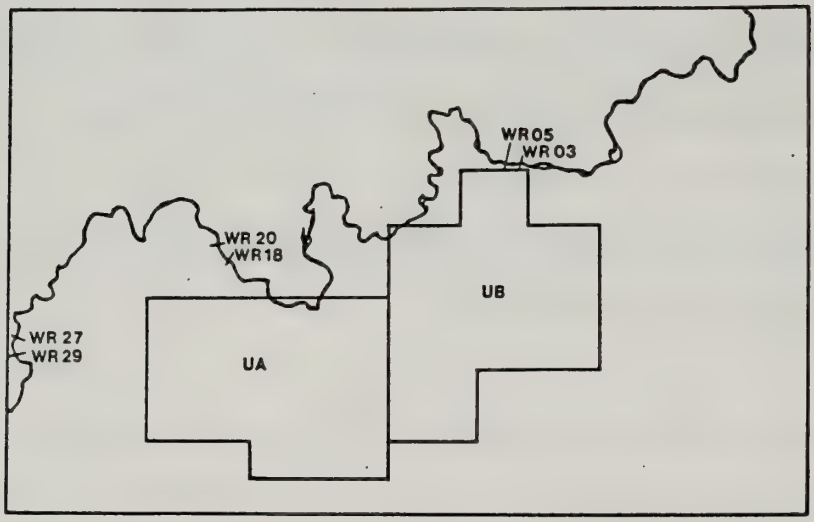


Figure 4.3-1 Aquatic biology monitoring locations in the White River during 1981 and 1982. Transects WR03, WR18, and WR27 are riffles and WR05, WR20, and WR29 are pools.

Subsequent to the publication of the EMM the recommendation was made to WRSOC to drop the pool transects. This was due to the high variability and low information value of these very unstable and biologically unproductive habitats as compared to the riffle transects. This change was approved and is presently in effect. Efforts during 1983 will be focused on continuing data collection at these riffle transects and, through experimentation,

refining sampling regimes and techniques to reduce data variability for better confidence in impact detection.

The EMM required that sampling on transects WR18 and WR20 occur monthly and the remaining transects be sampled quarterly. In conjunction with discontinuing the pool transects and with the "control-treatment" design required by the EMM for impact detection it was recommended that all riffle transects be surveyed monthly to provide a stronger data base for these statistical comparisons.

The EMM delineated three levels of monitoring parameters; operational, potential, and contingency. These parameters were described based upon nine months of data collection during 1981. It is expected that at the end of 1983, changes in these categories will occur, with some potential parameters becoming operational and others being moved into the contingent category. The completion of data analysis for the heavy metals study performed during 1982 should provide the data base necessary for future impact evaluations in this area.

Continuing development of production-respiration (P/R), and decomposition technology was carried on through 1982. Designs are presently being completed for the third generation P/R chambers and substrates. A completely redesigned system will be in operation by mid-1983. It is felt that future monitoring will rely heavily on these community-level or ecosystem parameters and this further refinement during 1983 will firmly establish these parameters as cost-efficient, "real-time" biological monitoring parameters.

The long-term program described in the EMM had three major objectives:

- To gather data which describes the aquatic ecosystem in sufficient detail to allow assessment of natural or project-related change.

- To organize data collection and analysis using a conceptual view of the ecosystem to determine the cause or pathway of these changes.

- To assess the effectiveness of mitigation and reclamation measures.

The data collected in 1981 and 1982 has allowed program refinement to proceed to the point that the assessment required by objective (A) was possible. That data coupled with the 1983 program will allow the initial development of a statistical model of ecosystem relationships which will aid in tracing impact pathways and assessing mitigation or reclamation measures. The attempt to construct these relationships will also aid in delineating program weaknesses which should be strengthened to allow impact detection and pathway analysis to proceed effectively. The data management and analysis program to be directed by ERI will lead to similar model development for all other WRSP environmental monitoring disciplines.

Another program objective required by the EMM was that each environmental discipline place into effect a quality assurance/quality control program to assure that data be complete, accurate, precise, and reliable. In the aquatic biology discipline, during 1982, these procedures

were implemented. All samples were logged into a master log book as required by the EMM. Other than standard instrument calibration, sample collection, and preservation procedures, quality control checks on chemical and biological analyses were instituted as required by the EMM. Specific examples follow.

One area of possible error once field samples arrived at the laboratory was in the area of invertebrate sample processing. Most of these samples had a large amount of organic debris and silt present and the separation of the invertebrates from this matrix required hand picking. Quality control measures for this process included randomly selecting samples which had already been picked and carefully repicking them. The invertebrates in the repicked sample were then identified, counted, and measured. Calculations were then performed to determine percent recovery of invertebrate numbers and biomass in the original sample as compared to the total of original plus repicked sample. Of total numbers present 79.1 $\pm$ 3.5 (s.e.) percent were recovered during normal sample processing (single picking). This represented 87.0 $\pm$ 7.0 (s.e.) percent of total biomass. The goal of this program is to recover 85% of numbers which normally represents 95% of biomass based on information generated to date.

It should be noted that these lower numbers were a result of two samples which had small numbers of invertebrates present so that missing a few individuals caused low percentages. In the majority of samples, approximately 98% of biomass was recovered.

To increase effectiveness of processing and achieve these goals, a Rose Bengal dye which differentially stains chitin in invertebrate exoskeletons is added to the samples prior to processing. This change in technique will be evaluated during the next quality control run.

Macroinvertebrate taxonomy is presently being verified by Dr. Wilfred Hansen, curator of the Insect Collection at Utah State University and a noted aquatic entomologist. He is evaluating the present White River reference collection and documenting any misidentifications to the level of genus.

In the area of water quality analysis, quality control standards were run for all analyses as part of the procedure for laboratory certification. Standards were obtained from EPA and the State of Utah Department of Health. Results from analyses of EPA samples are shown in Tables 4.3-1, 4.3-2, and 4.3-3. All White River parameters fell within the 95% C.I. Sample results for State of Utah standards were submitted to the State of Utah and the ERI water quality laboratory was granted certification.

As part of the ongoing quality control program required by the EMM these audit samples will continue to be run quarterly for internal quality control. On an annual basis, samples will be obtained from EPA and the State of Utah as part of the ongoing requirements for certification. Results of these analyses will be reported to those agencies for evaluation. All other quality control checks such as "spiked" samples will be run as part of normal laboratory procedure. Computer software is being developed to document precision and accuracy for all tests and monitor data generated for these tests for changes in precision and accuracy.

Table 4.3-1 Comparison of ERI values for mineral analyses with true values for audit samples provided by the U.S. Environmental Protection Agency. The mean recovery ($\bar{x}$) and the standard deviation (s) are listed with the true value and the 95% confidence interval.

Parameter	EPA Sample	True Value	$\bar{x}$	s	95% C.I.	ERI Value
pH	3	7.4	7.4	0.14	7.1-7.7	7.5
	4	8.6	8.7	0.15	8.4-9.0	8.5
Specific Conductance (umhos @ 25°C)	3	125	123	7.9	107-139	110
	4	479	478	25.5	427-529	439
Total Hardness (mg/l $CaCO_3$)	3	26.6	26.4	2.2	22.0-30.8	23.8
	4	109	108	3.5	101-115	106
Calcium (mg/l)	3	6.7	6.7	0.6	5.5-7.9	7.4
	4	32.0	31.7	1.5	28.7-34.7	33.9
Total Alkalinity (mg/l $CaCO_3$)	3	16.0	16.1	1.5	13.1-19.1	17.0
	4	73.7	73.6	1.9	69.8-77.4	72.0
Sulfate (mg/l)	3	12.0	11.7	1.3	9.1-14.3	10.0
	4	75.0	73.5	4.5	64.5-82.5	64.0

Table 4.3-2 Comparison of ERI values for nutrient analyses with true values for audit samples provided by the U. S. Environmental Protection Agency. The mean recovery ($\bar{x}$) and the standard deviation (s) are listed with the true value and the 95% confidence interval.

Parameter	EPA Sample	True Value	$\bar{x}$	s	95% C.I.	ERI Value
Ammonia-N	1	0.15	0.15	0.02	0.11-0.19	0.15
(mg/l)	2	1.52	1.52	0.09	1.34-1.70	1.42
Nitrate-N	1	0.18	0.18	0.02	0.14-0.22	0.22
(mg/l)	2	1.61	1.60	0.08	1.44-1.76	1.60
Orthophosphate-P	1	0.04	0.04	0.01	0.02-0.06	0.03
(mg/l)	2	0.27	0.27	0.01	0.25-0.29	0.26
Total-P	5	0.14	0.15	0.05	0.05-0.25	0.13
(mg/l)	6	1.04	1.06	0.06	0.94-1.18	1.06

Table 4.3-3 Comparison of ERI values for residue analyses, total suspended and dissolved solids, with mean recovery values ($\bar{x}$) for audit samples provided by the U. S. Environmental Protection Agency. The standard deviation (s) is listed with the 95% confidence interval.

Parameter	EPA Sample	$\bar{x}$	s	95% C.I.	ERI Value
Total Suspended	1	29.1	2.4	24.3-33.9	30.8
Solids	2	156	6.7	143 - 169	161
(mg/l)	3	534	21	492 - 576	569
Total Dissolved	1	456	18	420 - 492	435
Solids	2	300	20	260 - 340	292
(mg/l)	3	167	24	119 - 215	153

4.4. PROGRAM RESULTS AND ANALYSIS

4.4.1. The Physical Environment. Aquatic biology data collected during 1982 indicated that the White River in the study section was different from 1981. The physical environment within which the biota must exist was the dominant cause of this observed change. A characterization of sample sites and the dominant physical factors affecting stream biology follows.

4.4.1.1. Discharge. The dominant physical force operating on the channel morphology of most, if not all, streams is discharge. Discharge interacts with channel width to control channel erosion and deposition and sediment transport, thereby controlling the distribution and quality of habitats (Andrews 1982). Daily discharge values recorded by VTN during the period October 1980 until October 1982 are shown in Figure 4.4-1.

During 1982, discharge volume was generally of greater magnitude than in 1981. This general increase was due to changes in three major hydrologic components: lower basin runoff, upper basin runoff, and storm frequency and duration.

Lower basin runoff in 1982 had two major peaks in February and May as compared to a single peak in May, 1981. Upper basin runoff in 1982 peaked at 2500 cfs in May and endured until the end of July. In 1981, the peak occurred in June at 1700 cfs and only endured from early June until late June. During the summer of 1982, storm events were frequent as indicated by the large number of high flow pulses seen during July, August, and September. Storms were also frequent during the summer of 1981 but were not of the magnitude observed during 1982.

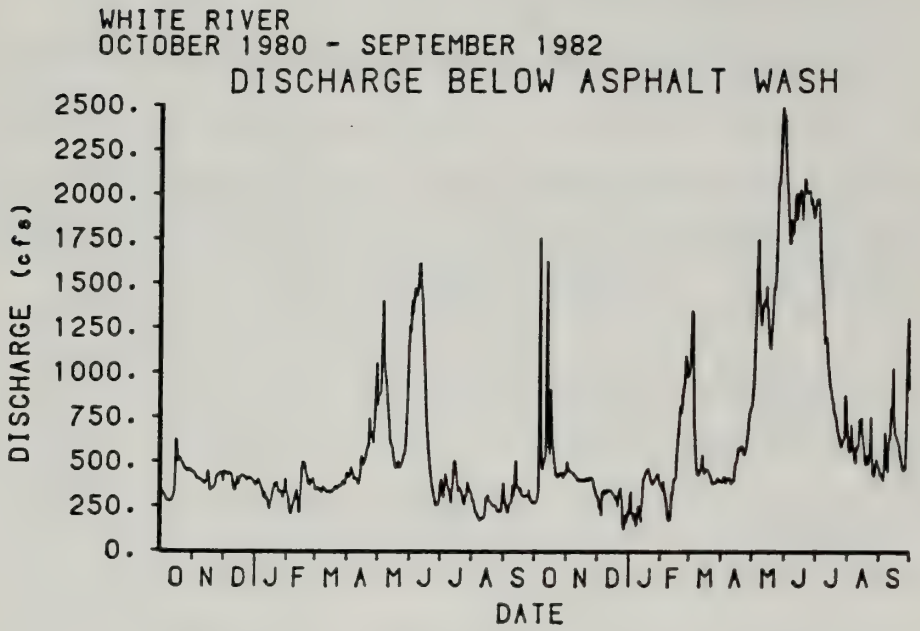


Figure 4.4-1 Discharge values reported by VTN for the White River below Asphalt Wash (near Southam Canyon) during 1981 and 1982.

These hydrologic events combined to alter habitats in 1982 as compared to 1981. The chemical and physical characteristics of the water were different in 1982 due to these same events.

4.4.1.2. Transect Characteristics. The mean physical characteristics of White River riffle transects WR03, WR18, WR27 and pool transects WR05, WR20, WR29 are summarized for 1981 and 1982 in Table 4.4-1. This table illustrates the differences between pools and riffles as well as the differences between years. Particularly, the effects of increased annual discharge were evident in the 1982 data.

During both years, the riffle transects were wider, shallower, and had greater velocities than the pools. The greater velocities coupled with

Table 4.4-1 Mean physical characteristics of White River transects during 1981 and 1982. Means calculated from total of all data collected along each transect during each year.

		Width (m)	Depth (cm)	Max Depth (cm)	Velocity (cm/s)	Max Velocity (cm/s)
Riffles						
WR03	1981	38.5	25.1	55.8	57.5	109.0
WR18	1981	40.1	31.0	59.5	69.4	141.9
WR27	1981	41.2	32.3	79.7	69.6	127.8
WR03	1982	45.9	32.1	68.2	63.6	122.7
WR18	1982	45.6	44.9	79.8	82.0	145.1
WR27	1982	39.3	48.1	110.8	72.4	125.4
Pools						
WR05	1981	35.7	37.1	68.8	46.0	78.5
WR20	1981	25.5	52.4	89.8	50.9	83.0
WR29	1981	29.7	46.4	104.3	45.1	85.2
WR05	1982	39.4	41.3	75.3	74.3	114.3
WR20	1982	29.6	59.1	111.0	64.3	105.8
WR29	1982	36.8	68.6	142.0	54.5	96.0
Potential control riffle transect upstream of tracts at Cowboy Canyon - single survey 820831						
WR00	1982	38.2	34.5	58.0	83.9	165.0

		Percent in Substrate Class						
		BO	CO	RU	GR	SA	SI	CL
Riffles								
WR03	1981	38.2	29.8	7.0	0.7	4.6	16.1	3.6
WR18	1981	42.6	31.4	20.1	5.0	0.0	0.5	0.5
WR27	1981	9.8	54.4	13.5	8.6	3.0	3.5	0.0
WR03	1982	40.2	25.2	13.7	10.2	4.8	6.0	0.0
WR18	1982	19.1	22.6	25.6	12.8	7.1	12.8	0.0
WR27	1982	9.2	22.3	25.3	11.4	12.7	19.0	0.0
Pools								
WR05	1981	20.4	11.7	21.5	16.3	17.5	12.8	0.0
WR20	1981	0.0	3.7	15.2	15.2	40.9	24.1	0.8
WR29	1981	23.4	14.8	2.3	0.0	28.7	23.5	7.2
WR05	1982	22.5	21.1	22.1	11.9	15.5	6.9	0.0
WR20	1982	4.3	1.7	8.2	15.7	48.6	21.6	0.0
WR29	1982	7.3	19.7	13.5	13.5	30.5	15.5	0.0
Potential control riffle transect upstream of tracts at Cowboy Canyon - single survey 820831								
WR00	1982	68.1	5.5	10.2	0.0	0.0	16.2	0.0

BO - Boulder
CO - Cobble
RU - Rubble
GR - Gravel
SA - Sand
SI - Silt
CL - Clay

greater turbulence which occurred on the riffle transects (Figure 4.4-2) resulted in elimination of smaller substrate sizes and dominance by the larger, more stable substrates.

Greater discharge in 1982 led to changes in both pools and riffles when compared to 1981. Both habitat types were wider and had increased depth and velocity. No apparent shifts in substrate dominance occurred in transect WR03 and the pool transects. WR18 experienced a shift to the intermediate sizes of substrate (CO, RU, GR) from BO, CO, RU in 1981. WR27 became more evenly divided among intermediate and small substrates (CO, RU, GR, SA, SI) from dominance by CO during 1981.

Interstitial sediment size fraction data taken from five sediment cores along each transect during 1981 and 1982 is presented in Figure 4.4-3. Riffle transects, in general, had a uniform distribution among the size fractions with the larger size fractions dominating. Pools, in general, had the opposite trend, being dominated by smaller sediment fractions. There were exceptions to these trends, however.

Transect WR03 experienced two periods of dominance by silt. Both of these periods coincided with lower basin runoff in 1981 and 1982 and could have reflected large sediment inputs from nearby Evacuation Creek. In the summer of 1982, silt levels remained high during the extended upper basin runoff period but then returned to normal conditions following runoff.

Transect WR18 experienced a single period of dominance by silt. This occurred during February, 1982 when an ice jam downstream near WR20 dammed the river and caused the deposition of large amounts of silt. During the

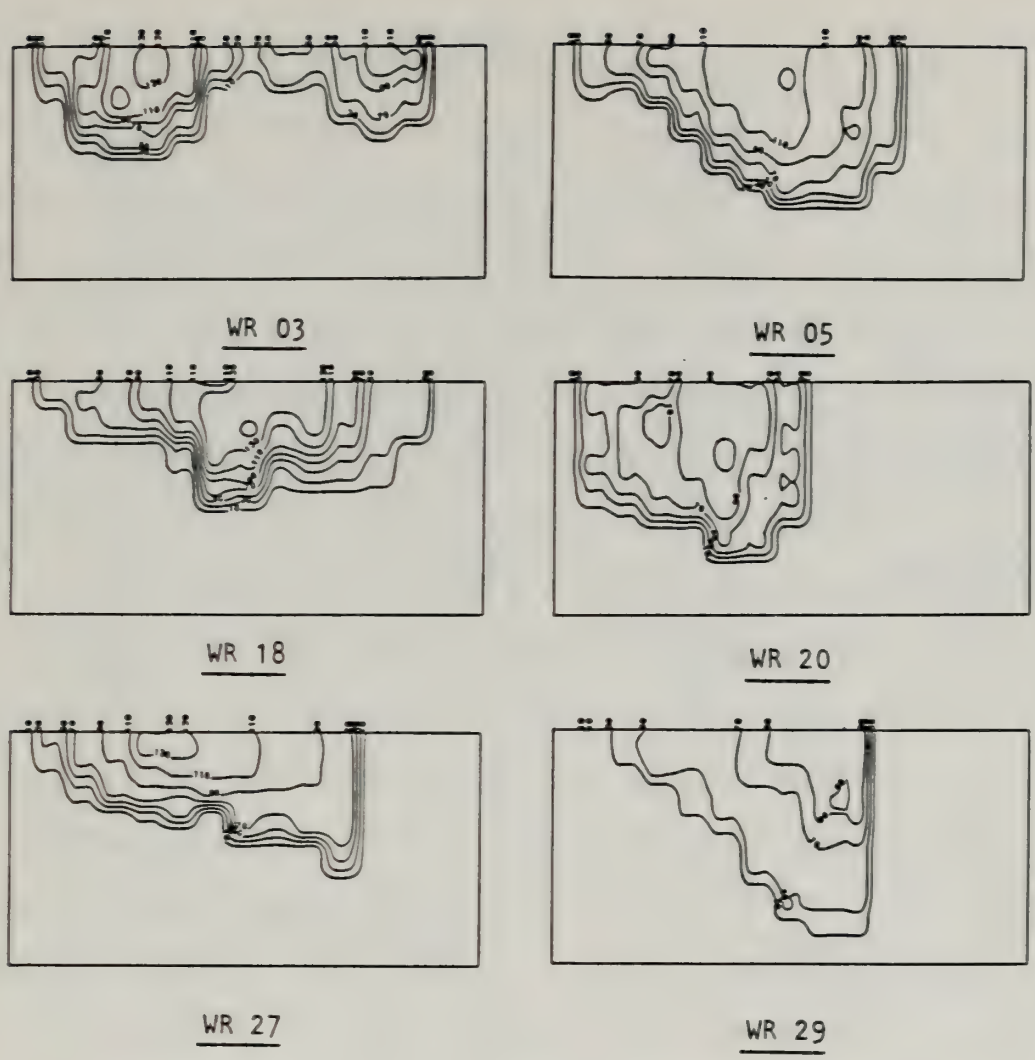


Figure 4.4-2 Velocity contours (cm/s) during the April, 1982 sample period for White River pool and riffle transects. Riffle transects are shown on the left while pools are on the right. Vertical scale exaggerated for illustrative purposes.

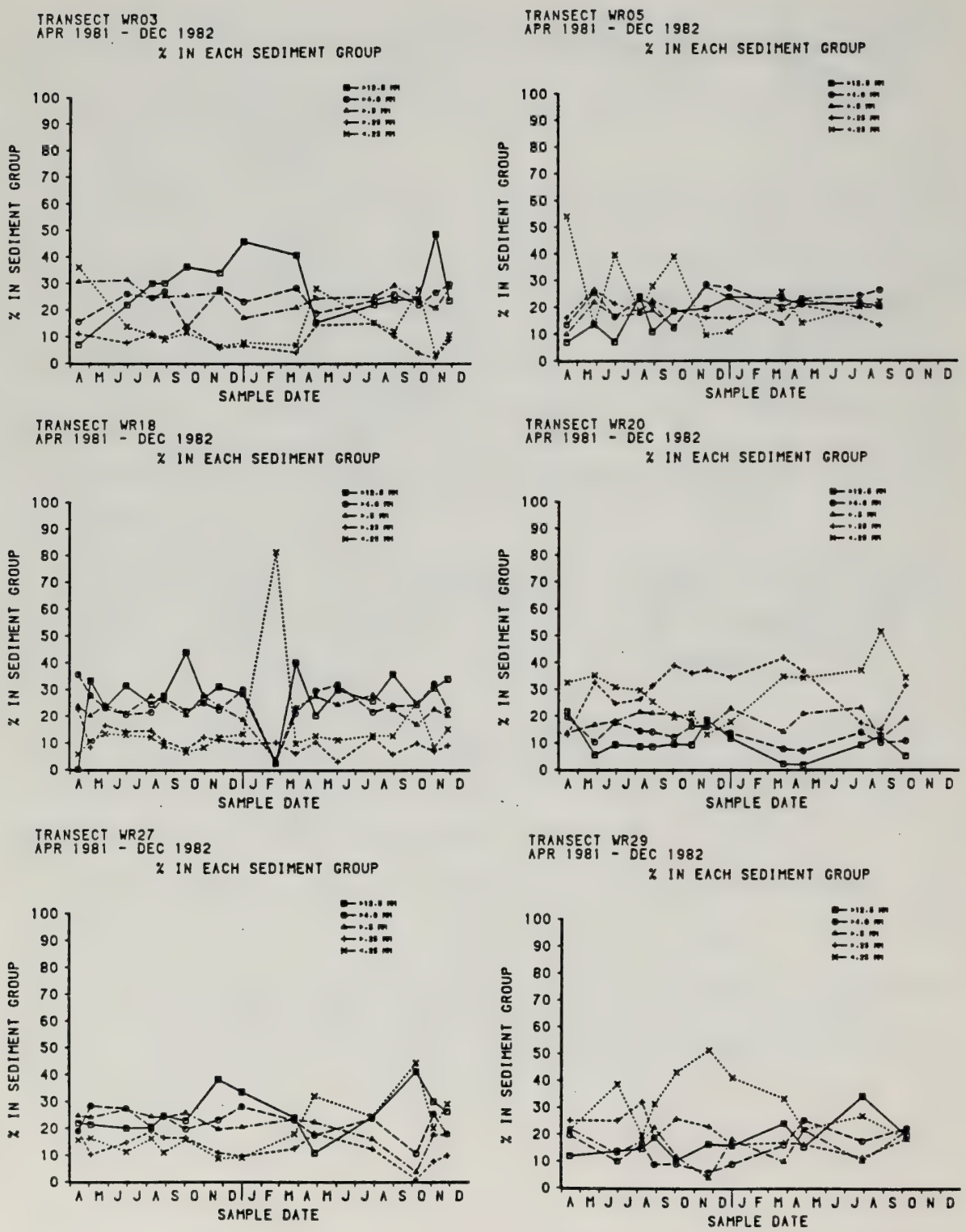


Figure 4.4-3 Percent of sediment samples occurring in each of five size fractions in six White River transects from April, 1981 to December, 1982. Left hand figures are riffles, right hand figures are pools.

remainder of both years this transect appeared normal.

Transect WR27 experienced a change in character during March 1982. At this time, the silt fraction increased to dominance and remained high until December. This was probably due to the less turbulent velocities occurring in this riffle transect which more closely resembled that of the pool transects. An additional factor which contributed to the increase in percent of fines, was migration of the stream channel into the fine alluvium of the south bank. This will be discussed under stream profiles.

Statistical comparisons considering the silt size fraction among the riffle transects reflected the observations noted above (Table 4.4-2). Two-way ANOVA comparing the three riffles by months showed that WR27 had a significantly higher percentage of silt than WR03 and WR18 ($p<0.05$). Across all transects there was a significant difference with September, 1981 being less than September, 1982 ($p<0.05$).

Considering Transect WR18 alone, there was a significant difference in silt percentage among months with December, 1981 being greater than all others ($p<0.005$). Two-way ANOVA considering years as well as months for WR18 showed that there was no significant difference between years or months.

Pool transect WR05 interstitial sediments were quite variable during both years with the smaller size fractions dominating during runoff events in 1981 and during low flow in March, 1982. During the remainder of 1982, the larger size fractions dominated. This transect did not display the consistent pattern of sediment dynamics exhibited by the other pool transects described below.

Table 4.4-2 Summary of sample periods and parameters included in statistical comparisons (ANOVA).

SAMPLING PERIOD	WR03,18,27 TRANSECTS AND MONTHS					WR18 MONTHS					WR18 YEARS AND MONTHS				
	Benthic invert.	chlorophyll a	Benthic organics	Sediment organics	Sediment size	Benthic invert.	chlorophyll a	Benthic organics	Sediment organics	Sediment size	Benthic invert.	chlorophyll a	Benthic organics	Sediment organics	Sediment size
1981 mid-Apr		X		X	X		X		X	X					
late-Apr						X	X		X	X	X	X		X	X
May						X	X	X	X	X	X	X	X	X	X
Jun	X	X		X	X	X	X		X	X	X	X			
Jul	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Aug	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sep	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Oct						X	X	X	X	X	X	X	X	X	X
Nov	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dec	X		X	X	X	X	X	X	X	X					
1982 Feb						X	X	X	X	X					
Mar	X	X	X	X	X	X	X	X	X	X					
Apr	X	X	X	X	X	X	X	X	X	X	X	X		X	X
May						X	X	X	X	X	X	X	X	X	X
Jun						X	X	X			X	X			
Jul	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Aug						X	X	X	X	X	X	X	X	X	X
Sep		X			X	X	X	X	X	X	X	X	X	X	X
Oct	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Nov	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Total (Max=20)	11	12	10	12	13	19	20	17	19	19	16	16	12	14	14

The remaining pool transects WR20 and WR29 had sediment size distributions that remained relatively uniform during both years with dominance by both silt and sand size fractions.

Stream cross-section profiles for each transect are presented in Figures 4.4-4 and 4.4-5. Each figure presents profiles before and after lower basin runoff during 1982. The effects of extended, high discharge were evident in all transects.

The upstream riffle Transect WR03, experienced a shift from smaller substrates in April (pre-runoff) to larger sizes in July (post-runoff). No significant change in channel morphology was observed. WR03 has retained consistent riffle characteristics through both years.

The on-site riffle transect, WR18, experienced a shift from smaller substrates in April (pre-runoff) to larger sizes post-runoff. No significant change in channel morphology was observed. WR18 has retained consistent riffle characteristics through both years.

The below tract riffle transect, WR27, did not undergo major changes in substrate between pre- and post-runoff, although changes from larger to intermediate substrates were observed between years. The major change in WR27 occurred in channel morphology. The channel width increased as the south bank of the river was eroded away. The streambed experienced some degradation as well. This transect, with its less turbulent velocity profile, shift toward smaller substrates and eroding banks appeared to be in transition from a riffle to a pool. These changes occurred due to the location of WR27 within a channel meander. This transect should be relocated

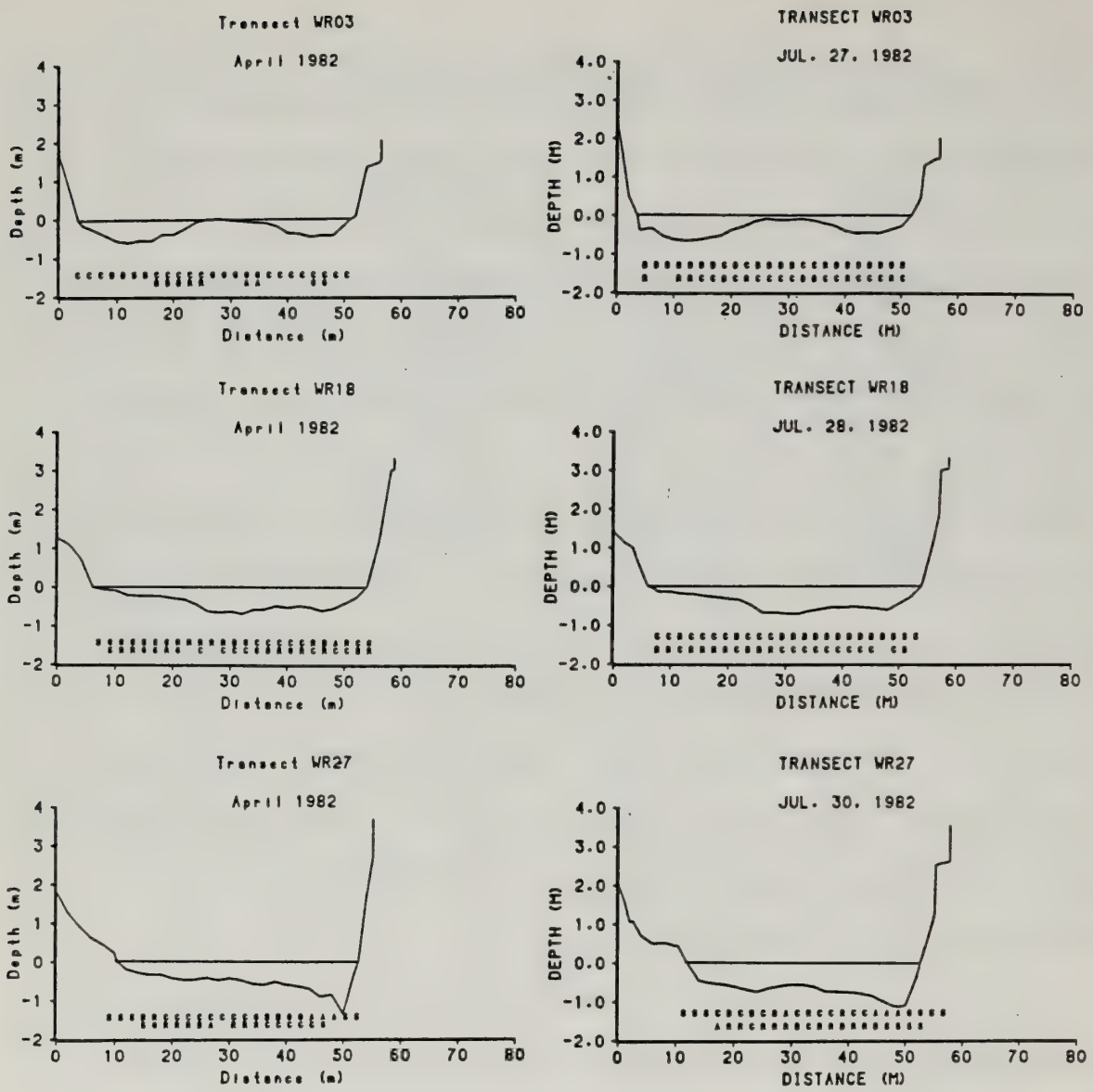


Figure 4.4-4 1982 pre- and post-runoff stream profiles for White River riffle transects.

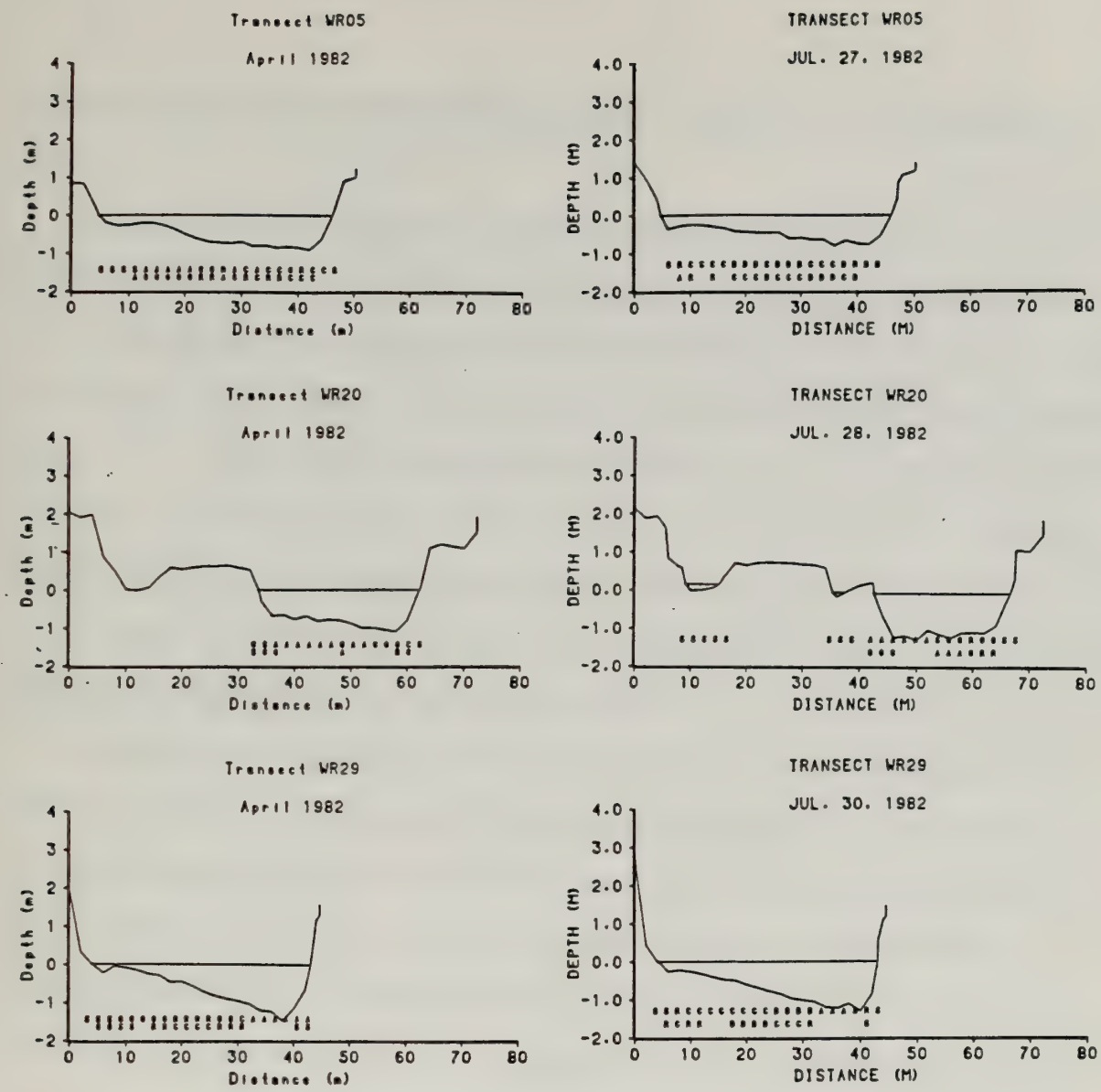


Figure 4.4-5 1982 pre- and post-runoff stream profiles for White River pool transects.

up- or downstream to a more stable riffle occurring within a straight section of stream channel.

The upstream pool transect, WR05, underwent a change from smaller substrates during April to larger substrates in July following runoff. This was due to erosion of the bed material during high discharge. Based upon higher velocities, larger interstitial sediments, and stream cross-sections this transect appeared to be intermediate between pool and riffle classification.

The on-site pool transect, WR20, experienced little change in substrate composition during the high discharge period, April - July, 1982. The substrate in this transect has always consisted, to a large degree, of sand and silt in apparent transport (high bedload). This transect underwent a large amount of channel erosion and deposition during this period. Five meters of the north bank eroded away with deposition of approximately ten meters of material onto the south side of the channel. This resulted in a migration of the channel approximately five meters to the north. The channel bed was also eroded downward. These changes were a result of the increased discharge in 1982 and the position of this transect in a channel meander. This transect remained pool-like in character and was the most unstable habitat sampled.

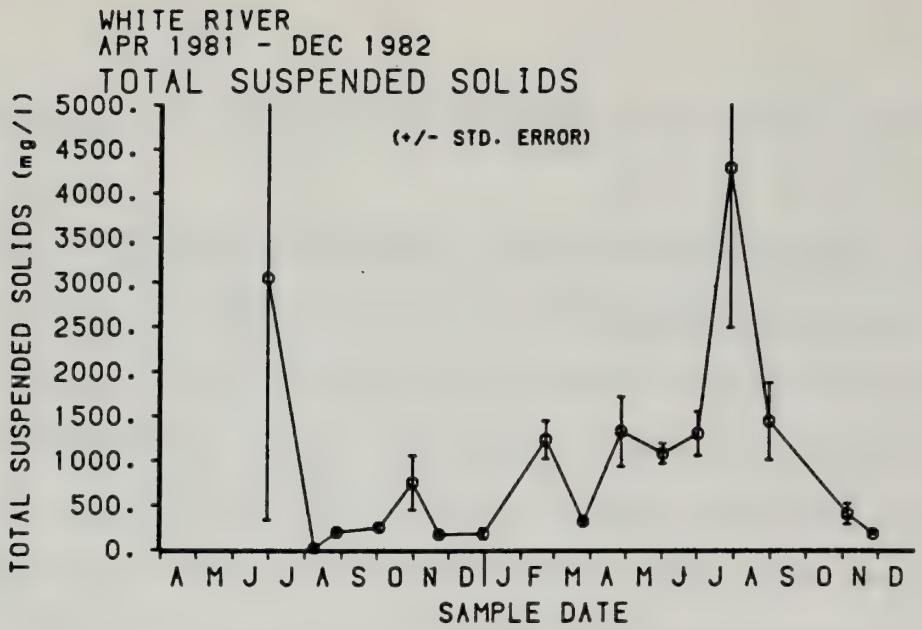
The below-tract pool transect, WR29, changed in substrate dominance between April and July, 1982. The smaller substrates present in April were eroded away, leaving the larger substrates exposed in July. Overall channel morphology did not change with the exception of a small amount of silt and

sand deposition in the deepest portion of the transect. This transect remained pool-like in character.

4.4.1.3. Total Suspended Solids. In the White River system during 1981 and 1982, particles suspended in the water were a dominant physical factor in regulating the biology of the system through scouring, siltation, and reduction in light penetration. In both years, total suspended solids were highest during upper basin runoff (Figure 4.4-6). This was probably due to bank erosion and inundation of nearshore areas during these high water periods. During the spring and summer of 1982, levels of suspended solids were generally higher than for a similar period in 1981. This reflected the higher discharge which occurred during 1982.

The variability in this parameter reflected events occurring in the watershed. During periods of baseflow or in the absence of storms, the variability was low as shown by the standard error bars in Figure 4.4-6. During storms or transition periods between major hydrologic events, variability was high. Examples of this will be illustrated in a later section.

4.4.1.4. Light Penetration. The depth to which one percent of photosynthetically active light penetrates (wavelength=660 nm) is shown in Figure 4.4-6. These values were calculated by an experimentally determined relationship (ERI 1982) between total suspended solids (TSS) concentration in the White River and light penetration (LUX) and therefore reflected the patterns observed in TSS. During periods of high discharge, TSS was generally elevated, resulting in a decrease in light penetration.



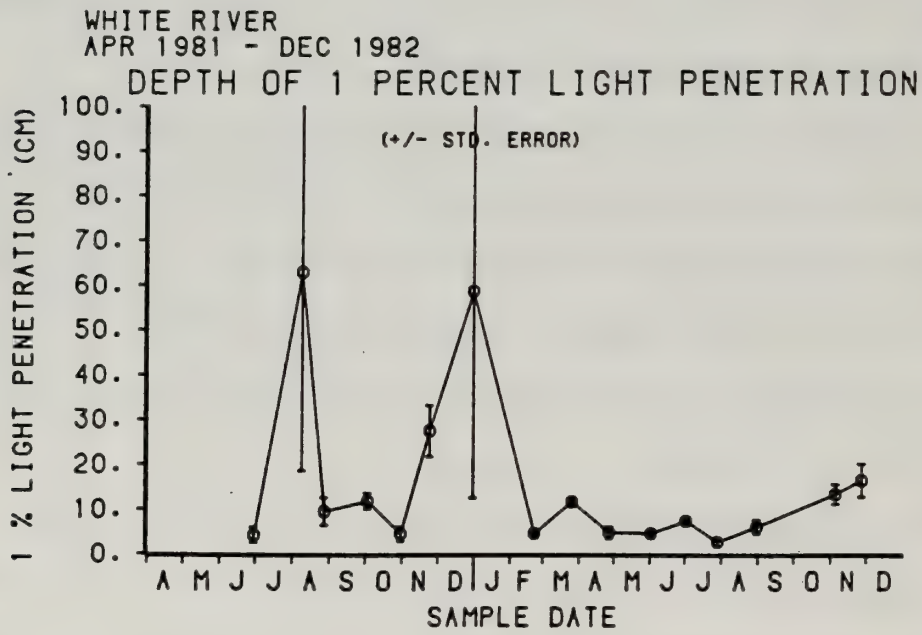


Figure 4.4-6 Total suspended solids and the depth to which 1% of incident light (660 nm) penetrated at Transect WR18 in the White River during 1981 and 1982.

During a large portion of 1982, light penetration was very low (<10 cm). This meant that very little of the river bottom had sufficient light for photosynthesis and that, in general, in-stream primary production should have been low. Chlorophyll a values for 1982 reflected this.

4.4.1.5. Water Temperature. Daily average water temperature values for the White River study area during the 1982 water year are presented in Figure 4.4-7. The data illustrated another aspect of the variability of the physical environment of the White River system. The annual temperature range was from 0°C to 25°C and while the trend followed a normal sinusoidal pattern, the short-term variations around the mean were substantial. These variations were due to runoff events and meteorologic factors.

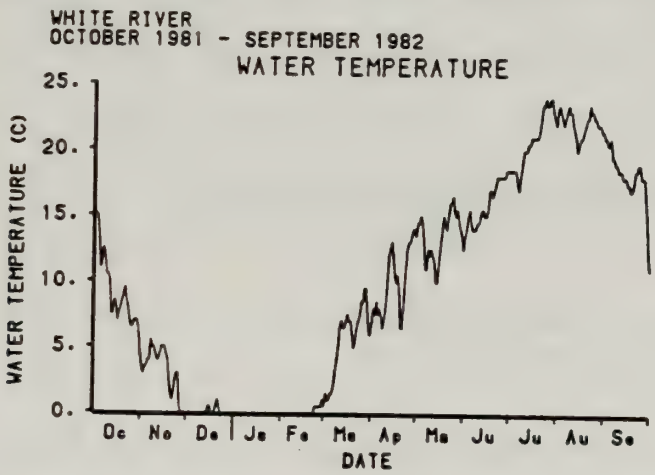


Figure 4.4-7 Daily average water temperature data for the White River 1982 water year. Data provided by VTN Consolidated for station near Asphalt Wash.

4.4.2. Chemical Environment. The chemistry of the White River in the study section is governed by the geology of the drainage basin, soils, and hydrology. The chemical parameters important to primary production are presented herein and reflect hydrologic or discharge-related events in the

watershed.

4.4.2.1. Conductivity. Conductivity, or specific conductance, is an indirect measure of the quantity of dissolved mineral substances in the water (APHA 1980). This parameter is biologically important in that it may indicate relative levels of osmotic stress or availability of micro- and macro-nutrients to the organisms inhabiting the White River. Figure 4.4-8 shows the variation in conductivity which occurred at WR18 during 1982 sample sessions.

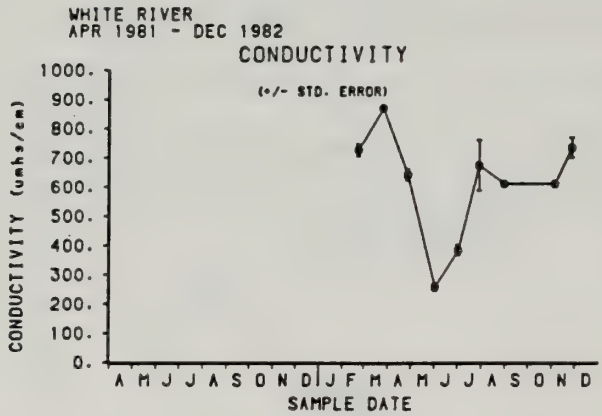


Figure 4.4-8 Conductivity in the White River at Transect WR18 during 1982 sample sessions.

During lower basin runoff in early spring, conductivity peaked near 900 micromhos/cm due to the leaching of dissolved substance from the soils of the adjacent watershed. As upper basin runoff began, dilution took place, lowering the concentration of these dissolved substances to approximately 200 micromhos/cm. With continuing high runoff through the summer and periodic storm with consequent leaching and overland runoff during the summer and fall, conductivities remained high through December.

4.4.2.2. Macronutrients. The inorganic forms of nitrogen and soluble reactive phosphorous (PO_4-P) are important to primary production in aquatic systems. The ratio of inorganic nitrogen to soluble reactive phosphorous has been used as a measure of nutrient limitation to the primary producers (Hutchinson 1967). The concentrations of these inorganic forms along with total phosphorous occurring in the White River during 1981 and 1982 are shown in Figure 4.4-9.

Total phosphorous, measured as both dissolved and particulate forms reflected hydrologic events which carried increased loads of suspended solids into the river. Thus, during periods of elevated discharge when TSS levels increased, total phosphorous in the river system increased. Levels during 1982 remained high through the year, while in 1981 they were low corresponding to the lower baseflow levels.

Soluble reactive phosphorous (designated orthophosphate), the biologically available form, followed the same pattern, with elevated levels during 1982 when compared to 1981. Again, concentration of PO_4-P tracked TSS and discharge while varying between approximately 1 μg/l and 13 μg/l.

Total inorganic nitrogen measured as the sum of nitrate (NO_3), nitrite (NO_2), and ammonia (NH_3) in the White River during 1981 and 1982 behaved in a similar manner to the phosphorous forms, again being determined by hydrologic events. The three compounds were present in order of concentration ($NO_3 > NH_3 > NO_2$) and reached maximum values greater than 500 ug/l during lower basin runoff.

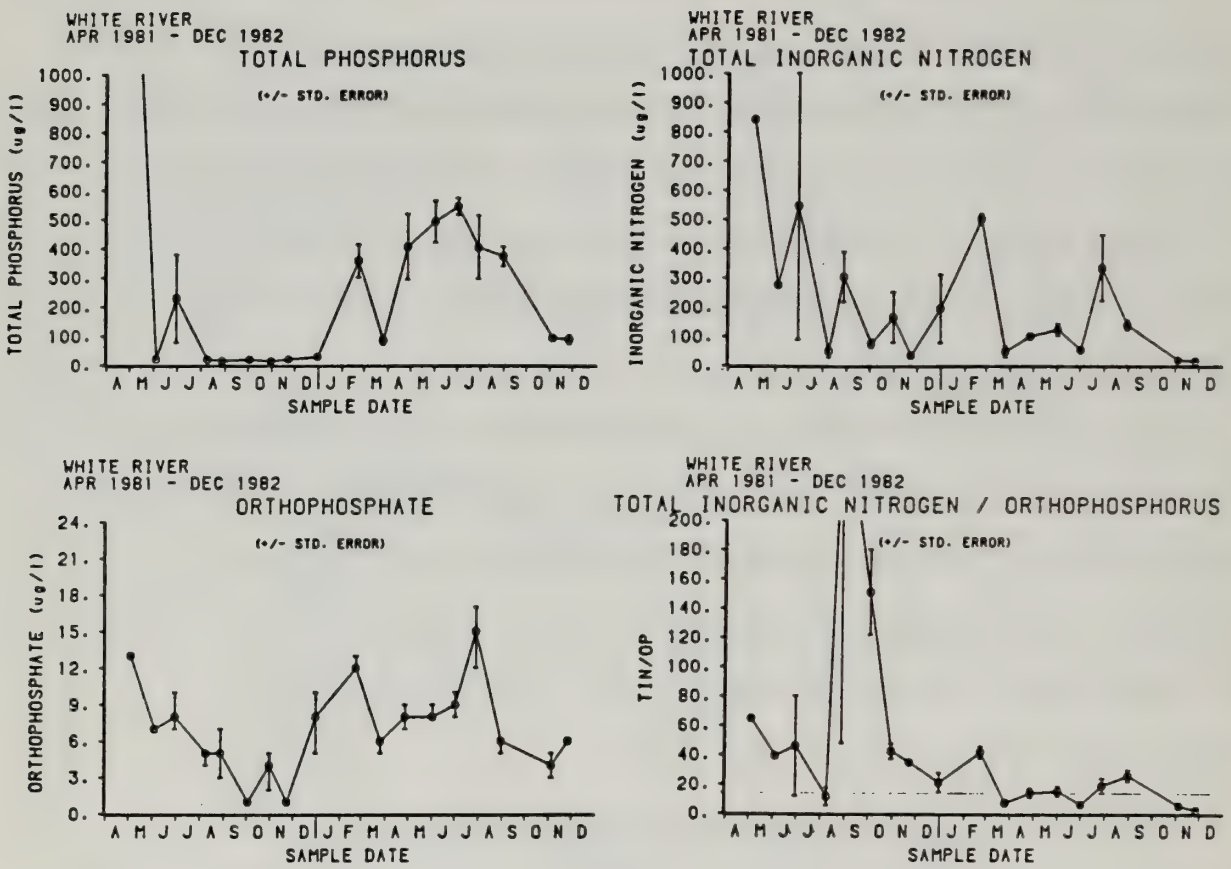


Figure 4.4-9 Total phosphorous, reactive phosphorous (orthophosphate), total inorganic nitrogen (NH_3 + NO_3 + NO_2) in the White River at Transect WR18 during 1981 and 1982.

The ratio of total inorganic nitrogen to orthophosphate has been used by limnologists to indicate when either of the major nutrients is in short supply relative to the other. When this ratio exceeds 15:1 the system is presumed to be phosphorous-limited and when the ratio is less than 15:1 nitrogen limitation occurs. According to Figure 4.4-9 the White River was phosphorous-limited during 1981 and oscillated between nitrogen and phosphorous limitation during 1982. Based upon the absolute levels of reactive phosphorous and inorganic nitrogen present in the system during those periods it appears that sufficient nutrients were available to promote primary production if other factors were suitable (light, substrate).

4.4.2.3. Storm Effects Upon the Physical/Chemical Environment. Following a lower basin runoff period during February and early March, 1982, the White River returned to a baseflow level of approximately 380 cfs. Data for a one week period during this time indicate consistent levels of physical and chemical parameters (Figure 4.4-10). Total phosphorous was declining during this period while the available forms of nitrogen and phosphorous as well as TSS and conductivity maintained uniform levels.

In contrast, following upper basin runoff during the last week in July the effect of a storm in the watershed was evident. During this week flow increased from 417 cfs on July 26 to 510 cfs on July 29 due to a storm. The resulting change in physical and chemical parameters occurred rapidly with the input of this storm (Figure 4.4-11). Conductivity and TSS rose sharply as did the concentration of total phosphorous and total inorganic nitrogen. These parameters reflected the input of silt and salts from overland runoff.

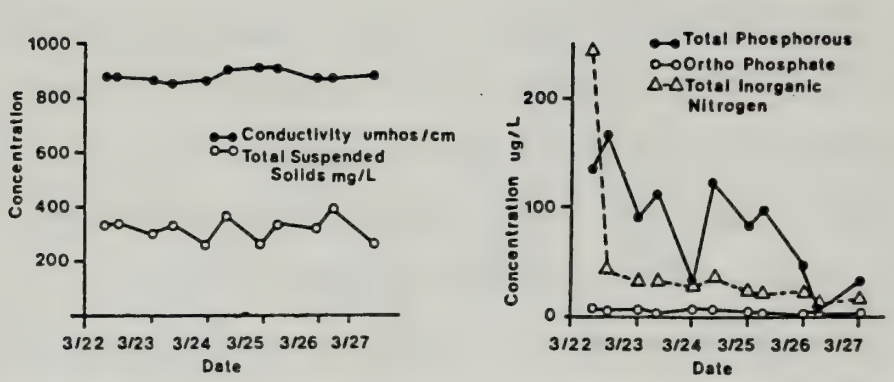


Figure 4.4-10 Water chemistry in the White River at Transect WR18 prior to upper basin runoff during March, 1982.

Orthophosphate increased from 8 µg/l to 30 µg/l during this period as well.

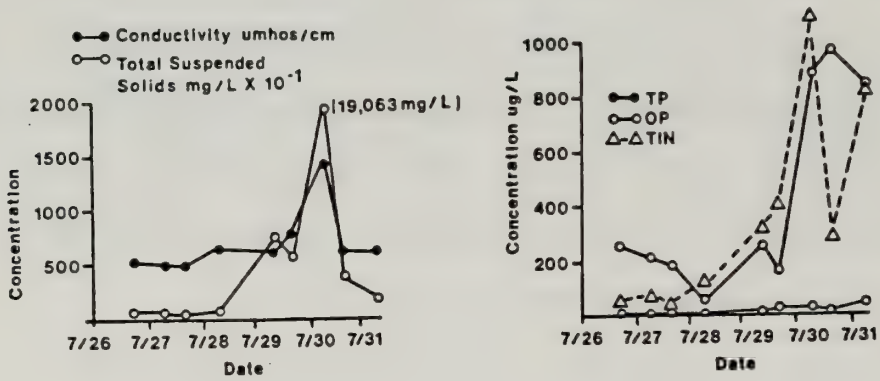


Figure 4.4-11 The effect of a storm event upon water chemistry in the White River at Transect WR18 during July, 1982.

Thus, periodic storms bring pulses of nutrients into the White River and can elevate annual levels of these nutrients if they occur frequently as in 1982. However, with storms, suspended sediments increase thus reducing light penetration and increasing scouring. These physical factors may then counter

the ability of the system to use increased available nutrients for primary production. Other system functions which require nutrients and do not require light, such as decomposition, may be enhanced by these storms.

4.4.3. The Organic Environment. River systems have two basic sources of energy (food) for the biota that exist therein. These are allochthonous or terrestrial detritus that reach the river via runoff or aerial transport and autochthonous organics generated within the stream by algae (periphyton) and macrophytes (plants). Land use patterns and runoff events are important factors governing the quantity of organic matter entering streams (Dance et al. 1979). During 1981 and 1982 it has been apparent from field observations that the White River was the recipient of a large amount of organic matter from the land. This input was measured by the use of drift nets which passively capture organic matter drifting through the study section.

4.4.3.1. Drift Organics. The amount and pattern of drifting organics which occurred in the White River adjacent to the tracts during 1981 and 1982 is shown in Figure 4.4-12. In general, the amount of drifting organics increases with increased flows. The July 1982 data point, which is extremely high, was based upon samples taken over extremely short time intervals due to very high silt loads which clogged the nets. The real value for this time period would likely be somewhat less than that shown.

4.4.3.2. Benthic Organic Matter (CPOM). Different species of bottom fauna have been shown to have different quantitative relationships with plant detritus. As a consequence, community structure at a single site has been

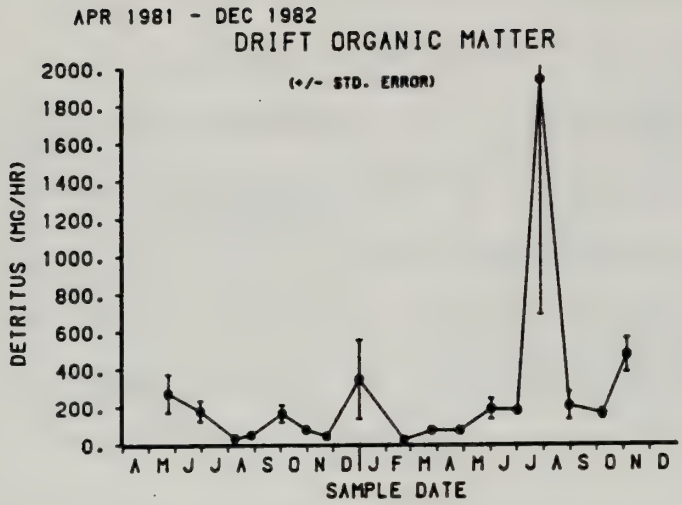


Figure 4.4-12 Dry weight of organic detritus drifting per square meter of river cross section in the White River at Ignatio Bridge and Southam Canyon from May, 1981 to Dec., 1982.

shown to depend to a large extent on the amount of detritus present. As amount of detritus increased, the variety of bottom fauna increased. In fairly uniform riffles, quantities of benthic species varied greatly with location and were correlated with amount of detritus present (Egglishaw 1969). Cummins (--) indicated in a review of the ecology of stream systems that primary production was the base of the food chain in erosional areas (riffles) while detritus was in depositional areas (pools).

The dry weight of benthic organic matter associated with benthic invertebrate samples during 1981 and 1982 is shown in Figure 4.4-13. CPOM (coarse particulate organic matter) in the riffle transects WR03, WR18, and WR27 reflect runoff events and, to some extent, primary production patterns. During high discharge, larger amounts of detritus entered the river system and were evidently deposited in the benthic region. This resulted in peaks

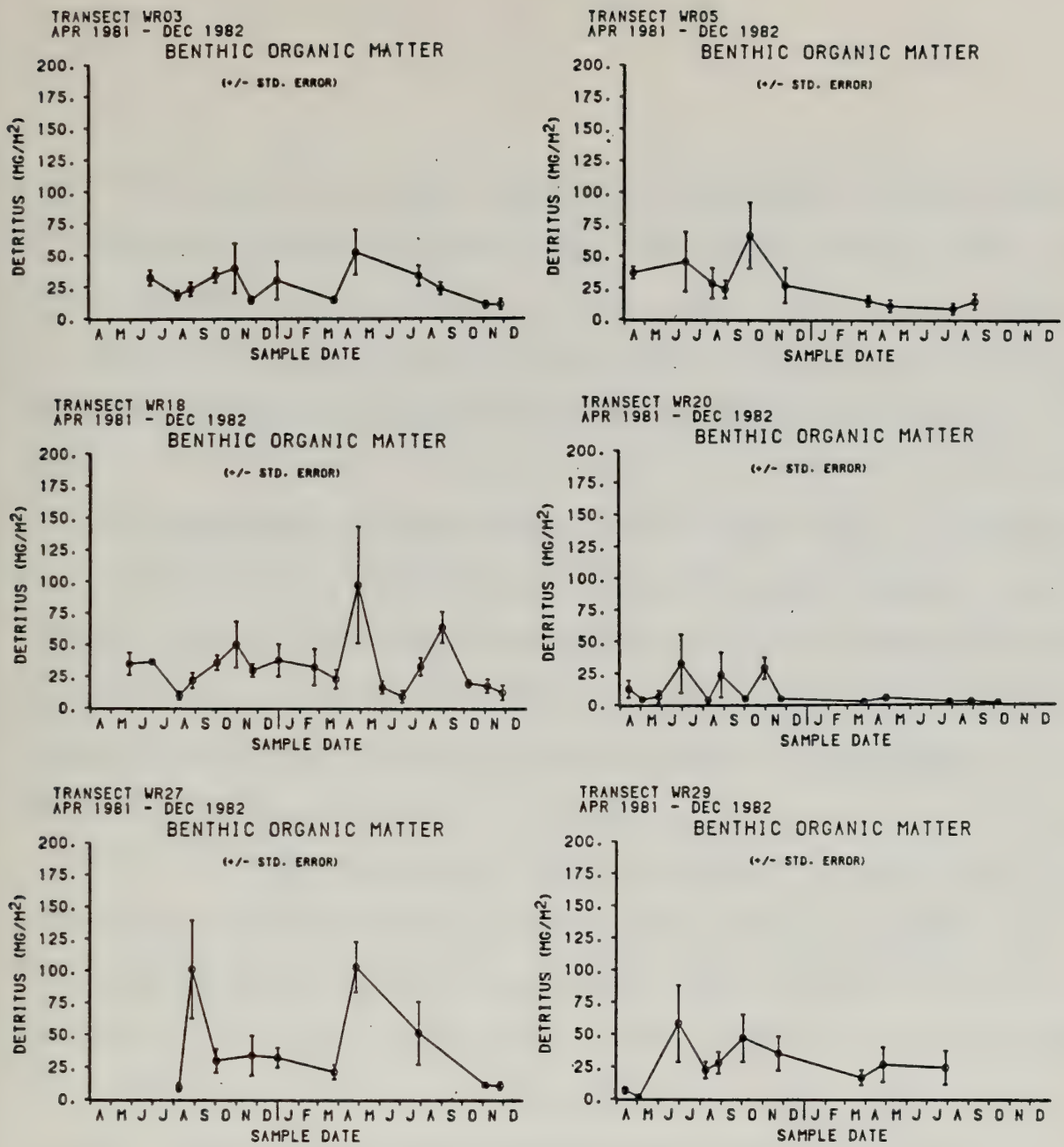


Figure 4.4-13 Dry weight of benthic organic matter (CPOM) associated with benthic invertebrate samples taken in six White River transects from April, 1981 to December, 1982.

in benthic CPOM during May, June, and October, 1981 and during April and August, 1982. Increasing amounts of benthic CPOM were measured during the late summer months of both years; however, during 1981 this was probably partly due to increased benthic production of filamentous algae. This was not the case during 1982 when algal production was low and storm frequency high.

Statistical comparisons of riffle transect data were performed to distinguish between transects by month (two-way ANOVA); to distinguish between all months for WR18, the intensive site measured most often, (one-way ANOVA), and to distinguish between years and months for WR18 (two-way ANOVA). Table 4.4-2 summarizes the number of sample periods included in each of these analyses. Data for pools was not subjected to statistical comparisons because these transects were discontinued as monitoring sites.

Two-way ANOVA showed that benthic CPOM did not differ significantly between transects based on monthly comparisons, but that some months were different ($p<0.05$) from others when all riffle transects were considered in the analysis. April, 1982 was significantly higher than all other months while July, 1981 was less than July, 1982 and November, 1982 was less than November, 1981.

Considering months for transect WR18 alone, there was a significant difference among months ($p<0.005$) with July, 1981 less than July, 1982 ($p<0.05$) and August, 1981 less than August, 1982 ($p<0.05$). A two-way ANOVA for WR18 considered the variation in benthic CPOM across years and months. There was no significant difference between years or months but there was a

significant interaction between years and months ($p<0.005$) which meant that variation was not consistent with each of these factors (i.e. the same temporal pattern did not occur).

These analyses resulted in increased confidence in benthic CPOM as a monitoring parameter. That the three transects were not different means the control-treatment approach to impact detection comparing upstream (control) sites with downstream (treatment) sites would be effective for this parameter without modification. Within transects, a few short-term (months) differences were detectable while years were not different. Most months were not different. This implies that impacts to this parameter may be detected with a resolution of years (coarse) and months (fine) with no change to sampling schedules.

CPOM in the pool transects was generally lower than in the riffles, probably due to the lack large of substrates with interstitial space to trap CPOM. The amount of CPOM present in the pools during 1982 appeared to be less than in 1981. This probably reflected the higher discharge and velocity during 1982 which would not have allowed detritus to settle to the benthic region in large quantities given the smaller, more uniform substrate.

4.4.3.3. Sediment Organic Matter (FPOM). The percent of the silt size fraction (<0.25 mm) from transect sediment cores which was combustible organic matter is shown in Figure 4.4-14.

FPOM (fine particulate organic matter) in the riffle transects WR03, WR18, and WR27 did not appear to reflect runoff events. There were no consistent patterns for all riffle transects although slight increases were

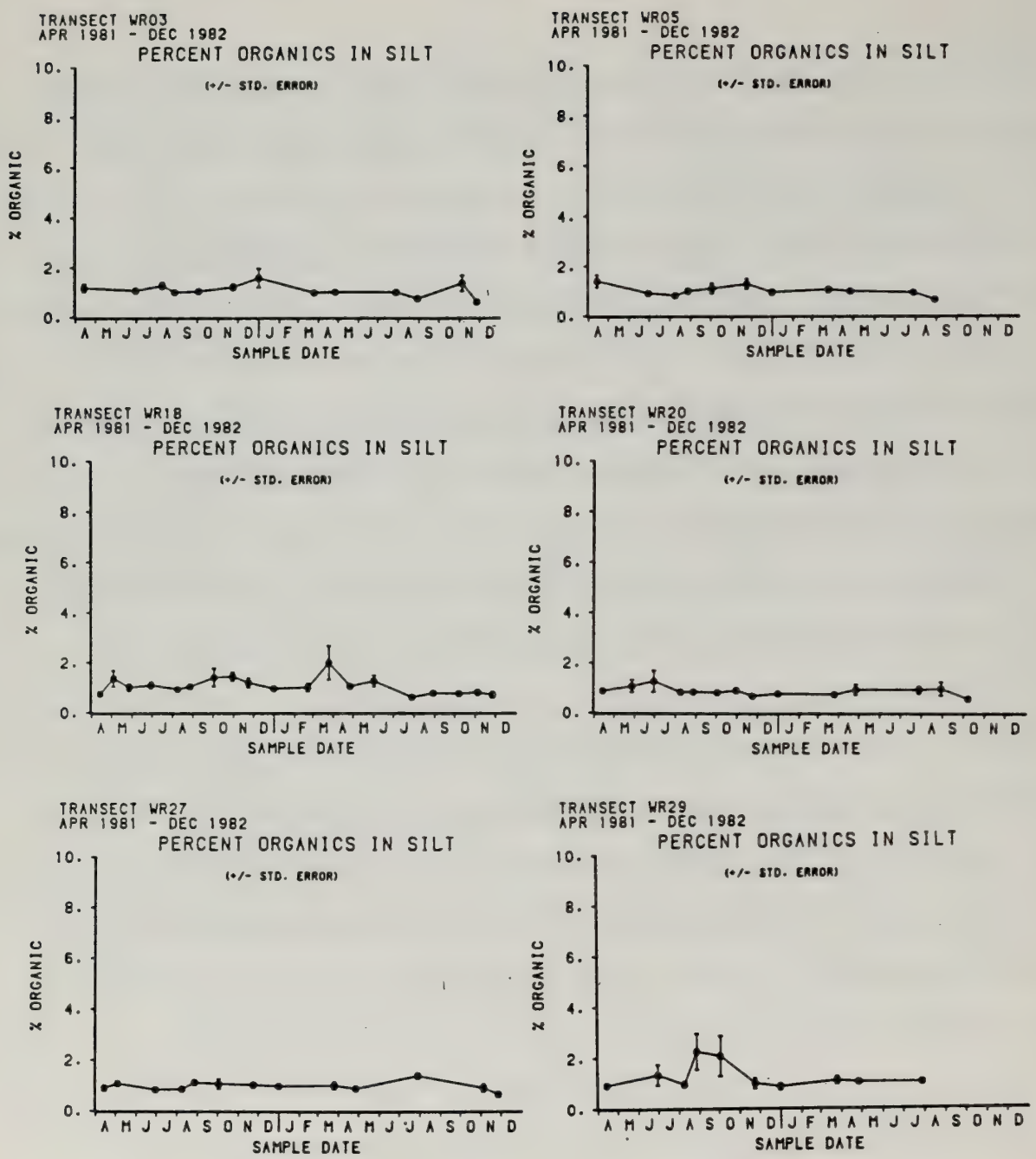


Figure 4.4-14 Percent organic matter (FPOM) as loss on ignition in sediment silt size fraction (<0.25 mm) in six White River transects from April, 1981 to December, 1982.

measured in all three transects during the summer and fall of 1981. This period of warm temperatures coincided with the period of highest invertebrate density and probably the highest microbial activity. These factors could have led to the processing of available CPOM to FPOM in the sediments.

The same statistical comparisons were performed on the FPOM data as for CPOM. Two-way ANOVA showed that sediment FPOM among the three riffle transects did not differ significantly based on monthly comparisons and there were no significant differences between months. One-way ANOVA performed on the intensive site, WR18, showed no significant difference between months. Two-way ANOVA of the WR18 data showed that sediment FPOM during 1981 was significantly higher than during 1982 ($p<0.01$) and that, again, there were no differences between months.

As was the case for benthic CPOM, these analyses resulted in increased confidence in sediment FPOM as a monitoring parameter. Since values have been very consistent between locations and time periods, control-treatment designs for impact detection are viable across location (transects) and time with a resolution of months.

FPOM in the sediments of pool transects did not appear different than in the riffle transects. No apparent pattern was observed which could relate sediment FPOM in pools to hydrologic cycles. The high values observed on WR 29 during August and September 1981 were due to the settling of silt in the shallow , low velocity portion of the transect during this period of low discharge. This type of area was not observed on any other pool transect, so no comparisons can be made.

4.4.4. Primary Producers.

The periphyton in the White River are an important source of energy for the consumers, the macroinvertebrates, and fish. Upon senescence they become an energy source for the decomposers and through decomposition and mineralization reenter the nutrient cycle of this aquatic system. Chlorophyll a was used as the dominant measure of the periphyton standing crop for the White River during 1981 and 1982 (Figure 4.4-15).

4.4.4.1. Periphyton Biomass. In general, desert streams tend to be more autotrophic due to the reduction of a stream canopy which allows greater light levels to occur within the stream (Blinn et al. 1981). As turbidity increases, photosynthesis decreases due to decreased light and gas exchange (Cordone and Kelley 1961).

Chlorophyll a in the riffle transects during 1981 and 1982 was governed by physical influences (Figure 4.4-15). During 1981 when discharge was low, light penetration was high and there was little scouring of the algae. Resulting standing crops were high. In contrast, during 1982, discharge remained high with resulting poor light penetration and substantial scouring by suspended sediment. Algae standing crops were consequently lower. The values attained in the White River were comparable to those found in the Little Lost River, Idaho study by Andrews and Minshall (1978). They found that the chlorophyll a content of periphyton was low (1-19 mg/m^2) following ice cover and spring runoff, but relatively high levels were found in late summer (12-68 mg/m^2). During the winter months of November through February in both years, scouring by ice was an important factor limiting algal

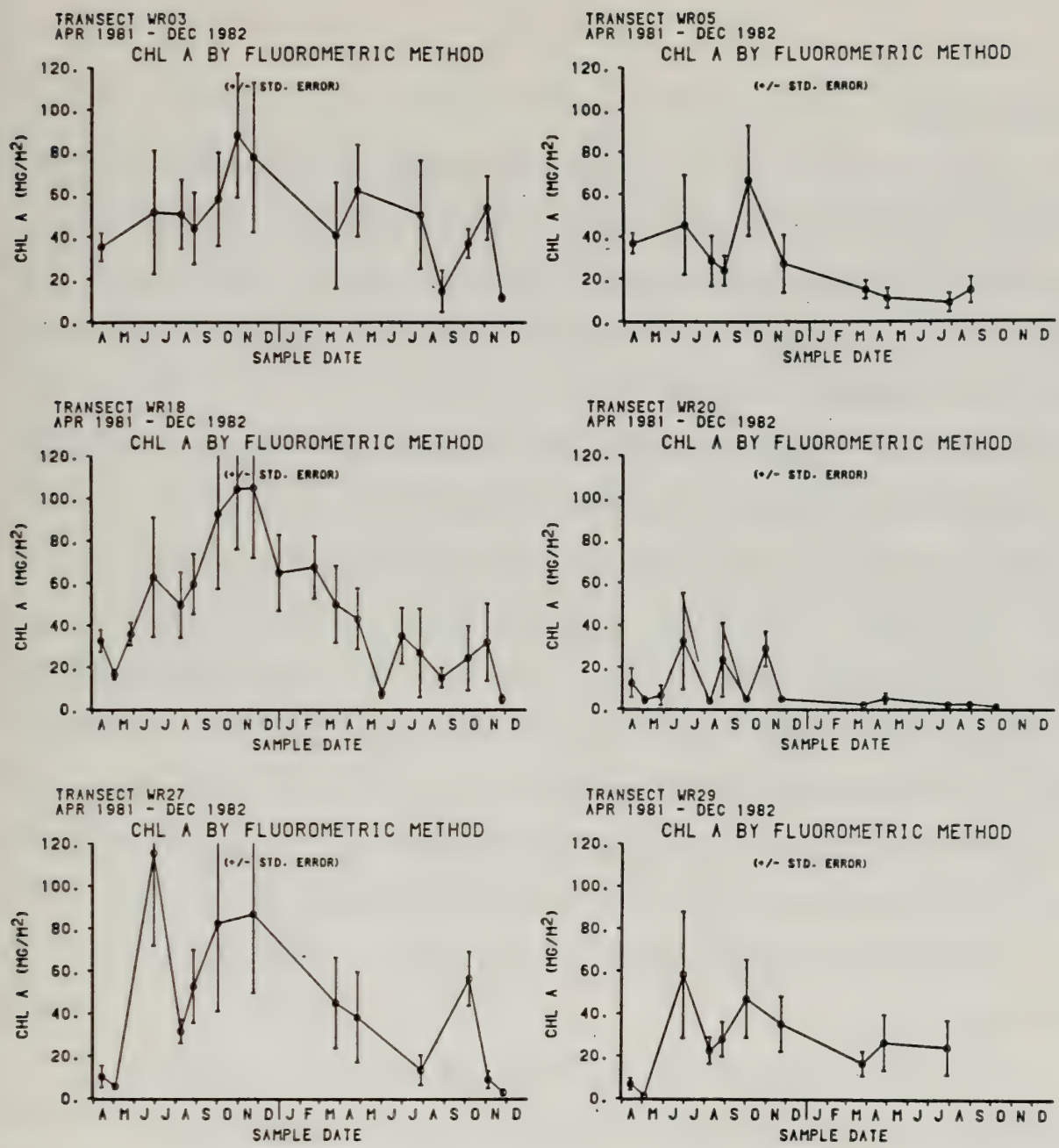


Figure 4.4-15 Periphyton biomass as chlorophyll a in six White River transects from April, 1981 to December, 1982.

standing crops.

According to the classical nitrogen/phosphorous ratio (Figure 4.4-9) the periphytic algae should have been phosphorous-limited during 1981. This was apparently not the case as phosphorous levels were lower in 1981 than in 1982, yet production was higher. Light was apparently the more limiting of these two environmental factors.

Two-way ANOVA comparing the three riffle transects by months showed that the three transects were not significantly different while there were significant differences among the months ($p<0.01$). November, 1982 was significantly lower in chlorophyll a than all other months ($p<0.05$) and July, 1982 was significantly lower than July, 1981 ($p<0.05$). Comparing months for transect WR18 only, there were differences among months ($p<0.01$). September, October, and November were all significantly higher in 1981 than in 1982 ($p<0.05$). Two-way ANOVA for WR18 considering differences among years and months showed that 1981 chlorophyll a values on WR18 were significantly higher than in 1982 ($p<0.01$) and that no months were significantly higher than any other.

Chlorophyll a values for riffle transects appeared to be a good biological monitoring parameter for the White River and can be used in a control-treatment design for impact detection. Since the transects were not different from each other over time, comparing upstream (control) transects with downstream (treatment) transects would have a good probability of detecting a change between locations. Since years were significantly different from each other, but few months were different from all others,

impacts or changes could be detected with a resolution of months and would depend upon sampling frequency.

Chlorophyll a for the pool transects was highly variable during 1981 due to the small amount of suitable substrate and the general instability of these environments which did not allow consistent production even though the light and nutrient climate was good. During 1982 the values were not as variable, probably because there were no periods of suitable conditions long enough to allow high production to take place. Standing crops remained low throughout 1982 reflecting this.

4.4.4.2. Production/Respiration. This potential set of monitoring parameters was measured during fifty-two separate experimental trials of from one to several days during 1981 and 1982. The results presented here are a gross summary of average values for each sample period (Figure 4.4-16). More detailed field tests and analytical and modeling efforts will take place during 1983 to bring the P/R information together into a refined monitoring tool. Results to-date are encouraging based upon field tests with stimulatory and inhibitory compounds.

The assimilation rate (mg O_2/mg chla/day) is the rate at which the standing crop of algae produces oxygen through photosynthesis over the amount required for respiration of the community attached to the rock surface. This rate is a measure of the efficiency with which the autotrophic community functions. Values are generally higher when the algal comunity is in a rapid growth phase with low standing crops (log phase growth). Thus, a small standing crop can produce an apparent "rate" much higher than higher standing

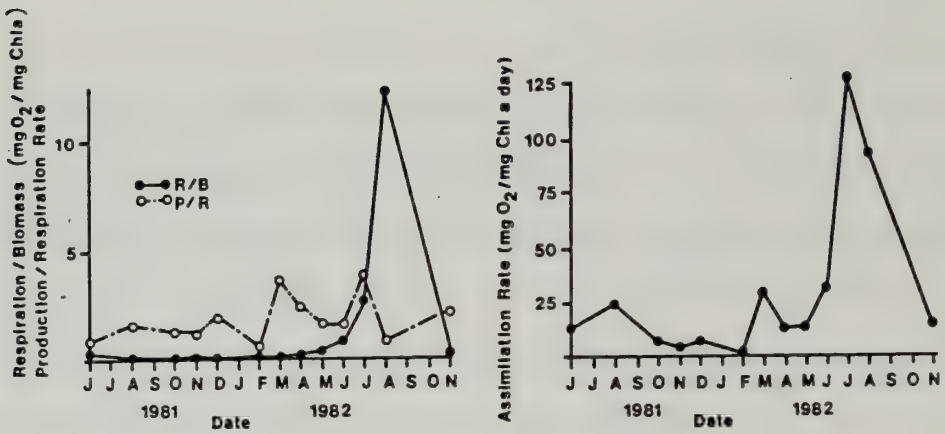


Figure 4.4-16 Results of production-respiration experiments in the White River during 1981 and 1982. Right curve depicts the assimilation rate or net production per unit mass of chlorophyll a present. The left figure represents community respiration per unit mass (R/B) of chlorophyll a present and the overall community production to respiration ratio (P/R).

crops yet be producing less oxygen per unit area.

During 1981 and 1982 the highest assimilation rates occurred during periods of higher light penetration and lower algal standing crops (Figures 4.4-6 and 4.4-15). The highest values occurred during August and September, 1982 and reflected short, highly productive periods of a few hours with low standing crops which had been inundated by very turbid water for long periods of time. This illustrates the rate at which the community can assimilate energy, even when favorable conditions are only available for short periods.

Respiration to biomass ratios which represent the amount of oxygen consumption by the community during the night remained low throughout 1981 and peaked during the summer of 1982 before returning to the previous low

levels. There is no clear explanation for this high value at this time. One hypothesis is that the extremely low standing crop of periphyton measured during this time period was extremely active as the assimilation rate indicated. This low, active biomass could have an extremely high specific respiration rate.

The production/respiration ratio (P/R) is the ratio of net daily production to respiration. Values greater than one indicate an autotrophic community, or one that produces more energy than it consumes, i.e. ruled by photosynthesis. Values less than one indicate heterotrophy, or a community consuming more energy than it produces. In the White River during 1981 and 1982, the periphytic communities measured were autotrophic (P/R>1) or nearly so during all sample periods except February, 1982. This period had a high standing crop of periphyton but light penetration was poor which led to a community of algae continually respiring with no net oxygen production.

Once a model is developed which integrates light into the rates of production and respiration these values will be much more easily interpreted and tested statistically for impact detection. Other factors such as light adaptation, physiological state of the algae, and most appropriate light quantum measurements will be considered in the model.

4.4.5. Consumers. The consumers measured on transects in the White River aquatic biology program during 1981 and 1982 were the macroinvertebrates. The taxa were dominated by members of the class Insecta.

4.4.5.1. Species Richness. This parameter was based on taxonomy to the level of genus and should more appropriately have been called "taxonomic

richness". However, common terminology (species richness) governs here. Crossman et al. (1973) justified taxonomy to the genus level rather than species because it allowed an increased scope of investigation due to cost savings both in time and dollars. Using genera was effective in that comparisons could still be made with a comparable level of discrimination. Coleman and Hynes (1970) found in experimental studies with introduced substrates, that full colonization of animals would take in excess of 28 days while representatives of nearly all taxa were present in samples after one day and all were present by day three. This indicates the importance and rapid response of this parameter.

The riffle transects all exhibited a similar pattern of higher species richness during the summer months and lower richness during the winter months (Figure 4.4-17). Most or all of the taxa were present at all times, but normal sampling techniques can miss the egg or smallest instars. The high summer richness values represented rapid growth (and therefore high sample visibility) due to higher temperatures and better food availability. During 1981 there was a very regular pattern of increasing richness and, with emergence, a regular decrease and leveling off during the winter inactive stage. In 1982, this regular pattern was made more erratic by the high discharge events which continually disturbed the macroinvertebrate community. Emergence patterns could have been altered or these disturbances could have been lethal to some genera. Andrews and Minshall (1978) found that ice, temperature, discharge, and food availability exerted a strong influence upon the invertebrates of the Little Lost River, Idaho. There was a strong

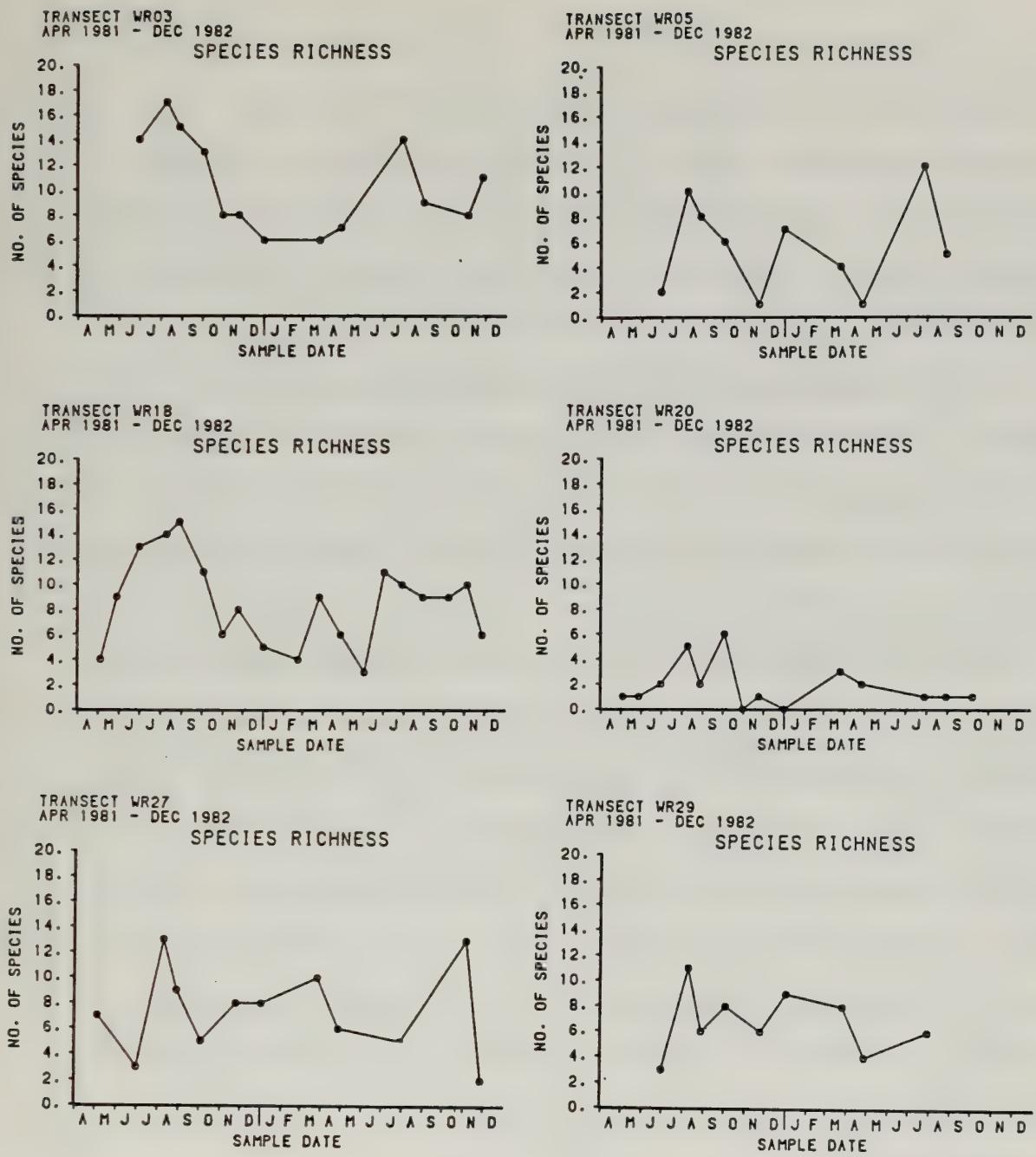


Figure 4.4-17 Benthic macroinvertebrate species richness in six White River transects from April, 1981 to December, 1982.

correlation between total numbers and mean annual discharge.

The instability of the pool transects was depicted well by the macroinvertebrte community (Figure 4.4-17). Species richness was highly variable and had no pattern. This was one of the factors considered before discontinuing monitoring at these sites.

4.4.5.2. Macroinvertebrate Density and Biomass. The numbers and biomass of macroinvertebrates captured on pool and riffle transects in the White River during 1981 and 1982 are shown in Figures 4.4-18 through 4.4-20. These values are presented by functional group representing the food base of the organisms as well as the totals.

Numbers and biomass of riffle macroinvertebrates followed a similar pattern as periphyton biomass with peaks occurring during low discharge and high light periods during 1981. This indicated that similar environmental conditions and perhaps partial dependence upon a periphytic food base were important factors in determining macroinvertebrate abundance. As stated earlier, Andrews and Minshall (1978) found a strong correlation between total numbers and mean annual discharge. Cummins (--) also pointed out the importance of velocity to the macroinvertebrate community. These factors appear to be of great importance to the macroinvertebrate community of the White River as well.

Two-way ANOVA which considered the three riffle transects by months showed that WR03 and WR18 were significantly higher in numbers and biomass than WR 27 ($p<0.05$). This was due, in part, to the lack of boulders and less stable smaller substrates generally present on WR27 as compared to the other

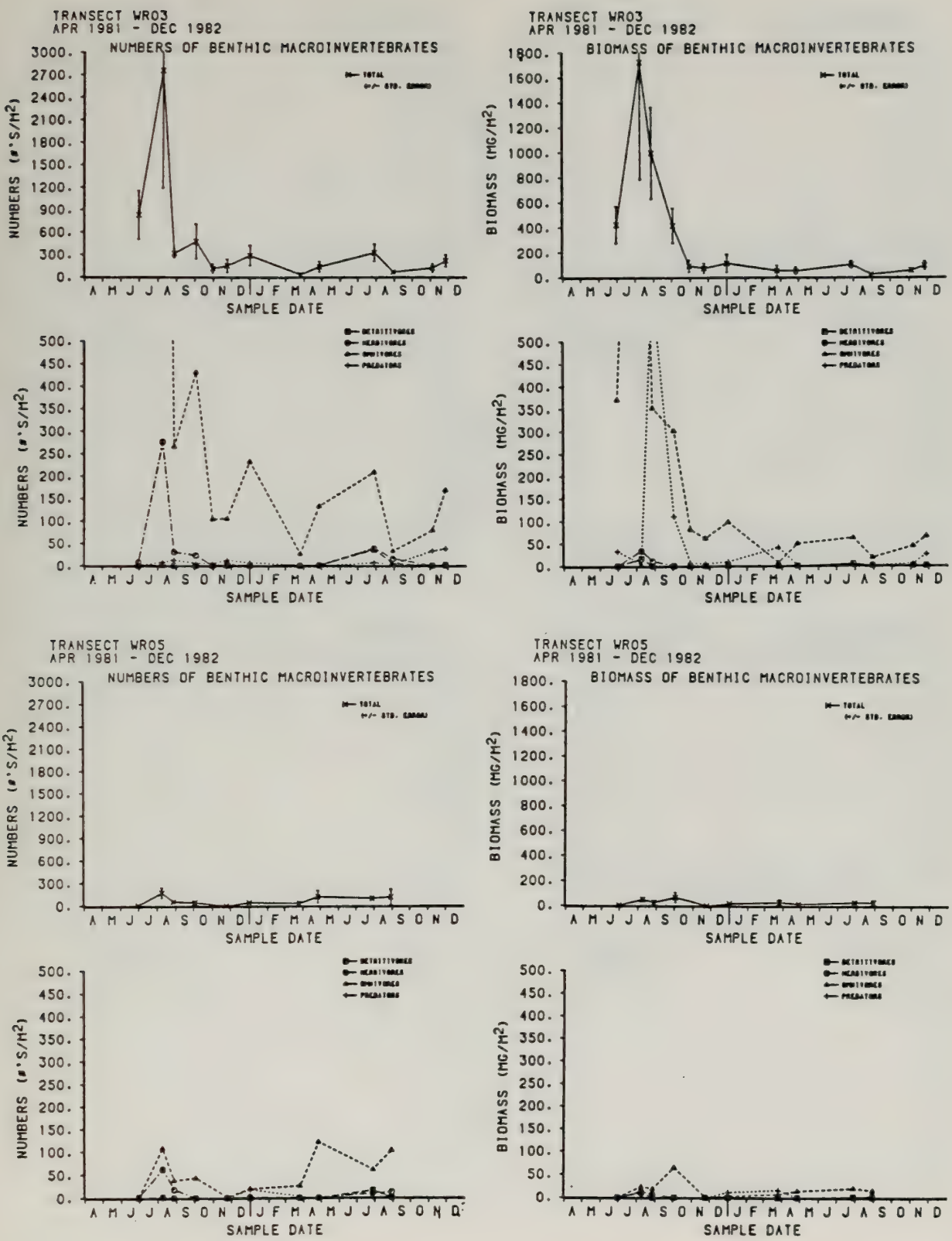


Figure 4.4-18 Numbers and biomass of benthic macroinvertebrates by functional group and totals for White River Transects WR03, WR05 from April, 1981 to December, 1982.

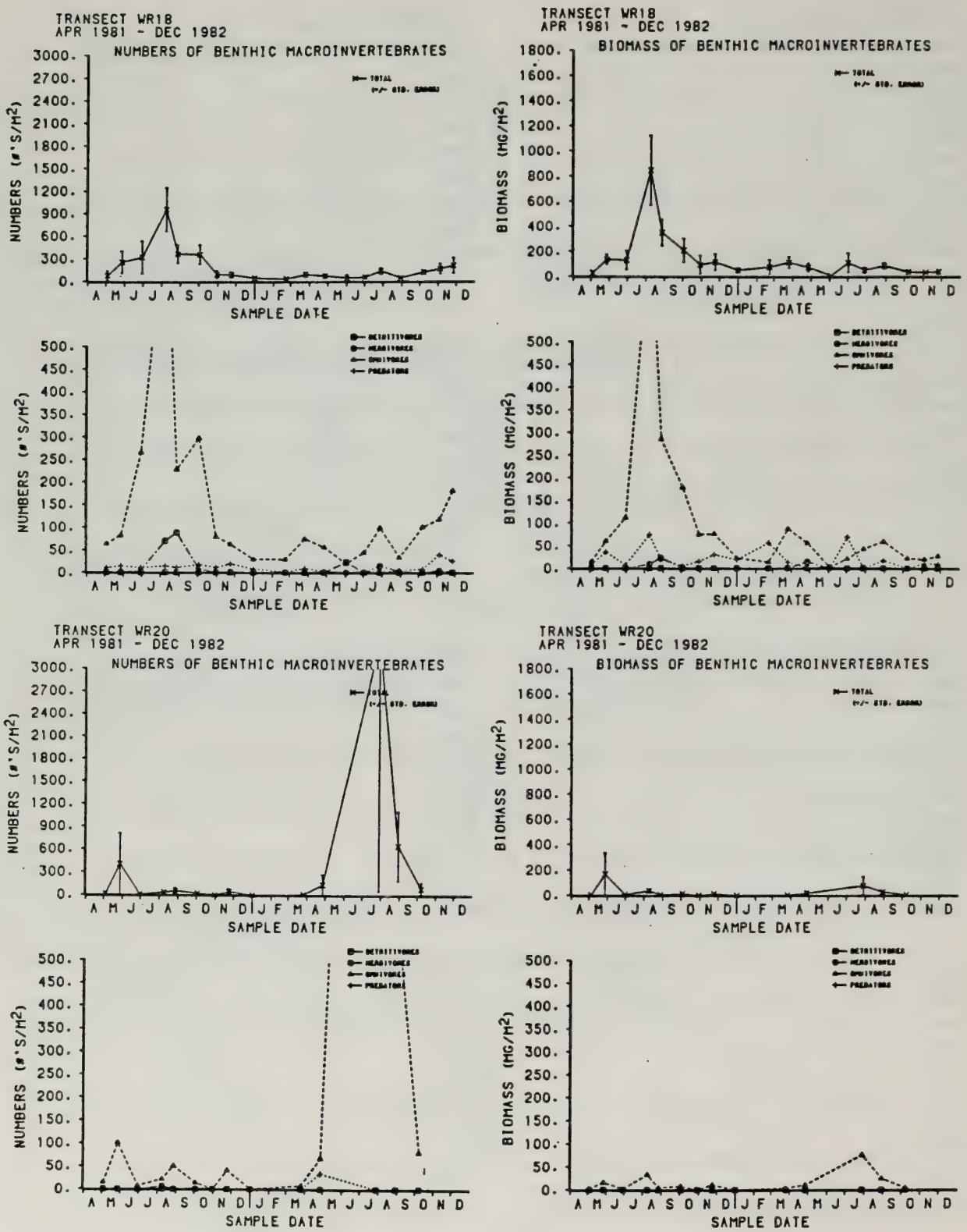


Figure 4.4-19 Numbers and biomass of benthic macroinvertebrates by functional group and totals for White River Transects WR18, WR20 from April, 1981 to December, 1982.

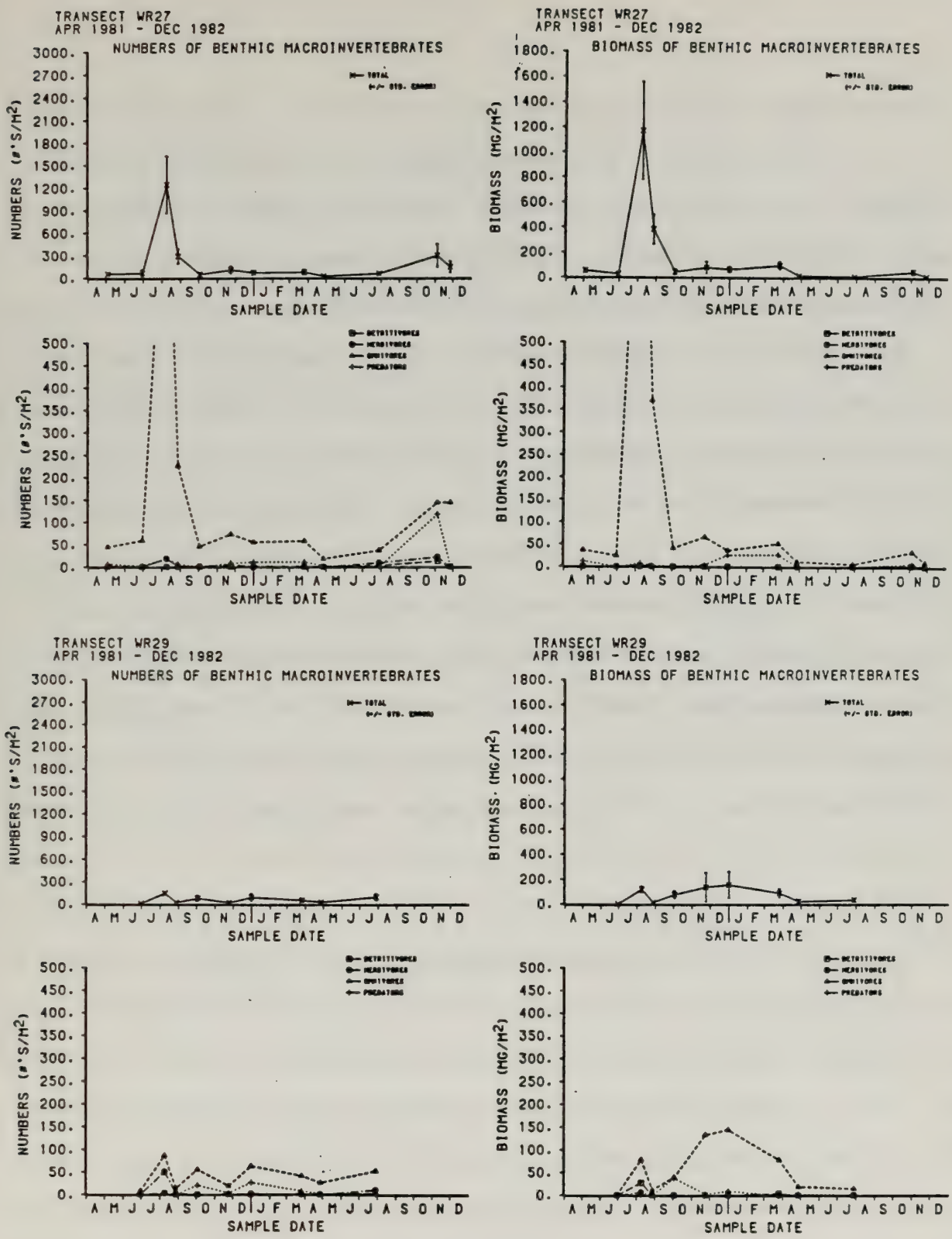


Figure 4.4-20 Numbers and biomass of benthic macroinvertebrates by functional group and totals for White River Transects WR27, WR29, from April, 1981 to December, 1982.

riffle transects.

In this analysis, some months were shown to be significantly different when all riffle transects were included. Biomass was higher in July and August, 1981 than other months ($p<0.05$) while numbers in July, 1981 were higher than all months except August, 1981 ($p<0.05$).

Considering these parameters for WR18 alone by months differences were also found. Biomass was higher in May and July, 1981 than during the same months in 1982 ($p<0.05$). Numbers were higher in July and August, 1981 than during the same months in 1982 ($p<0.05$). When numbers and biomass occurring on WR18 were compared by years and months in a two-way ANOVA, both were significantly higher during 1981 than 1982 ($p<0.01$, $p<0.005$, respectively). There were significant differences for both parameters among months as well. Numbers and biomass were higher in July than in April, May, June, October, and November ($p<0.05$), while August biomass was higher than in April, June, October, and November ($p<0.05$). August numbers were higher than in November ($p<0.05$).

The difference shown between riffle transects using ANOVA indicates problems in using a control-treatment design directly. A relationship taking into account the normal differences between WR27 and the transects WR03 and WR18 would be necessary in order to construct an appropriate model for using the control-treatment impact detection method such that no difference exists during normal (impact-free) periods. Sensitivity will have to be increased through reduction of sample variability before impacts can be detected on any time scale less than years. An investigation to achieve this result will be

conducted during 1983. Relocation of the downstream transect WR27 to achieve a more stable habitat will be considered as well.

The omnivore functional group was higher in numbers and biomass in all three riffle transects during 1981 and 1982 than any other group. This group of organisms, being "generalist" in nature were better able to cope with the variable environment of the White River during these two years. Biomass of predators was important during times when total biomass and numbers were high, generally during the more productive summer periods. Herbivores became significant during periods of high primary production and favorable temperatures, principally the summer of 1981.

Numbers and biomass of benthic macroinvertebrates were generally low in the pool transects during both years when compared to the riffles. There was no apparent pattern to the distributions through time. A large number of individuals was found in WR20 during July, 1982. This was principally due to the presence of a highly productive backwater on this transect during this period. Functional groups were dominated by omnivores as in the riffle transects.

4.4.5.3. Drifting Macroinvertebrates. An important recolonization method for macroinvertebrates is their ability to drift downstream with the current and invade new substrates. The species richness found in drift samples during 1981 and 1982 is shown in Figure 4.4-21. Richness in the drift appeared to be high when discharge was high and scouring, either by silt or ice was occurring. Apparently, the effects of these natural perturbations were felt by most taxa inhabiting the river. Numbers and

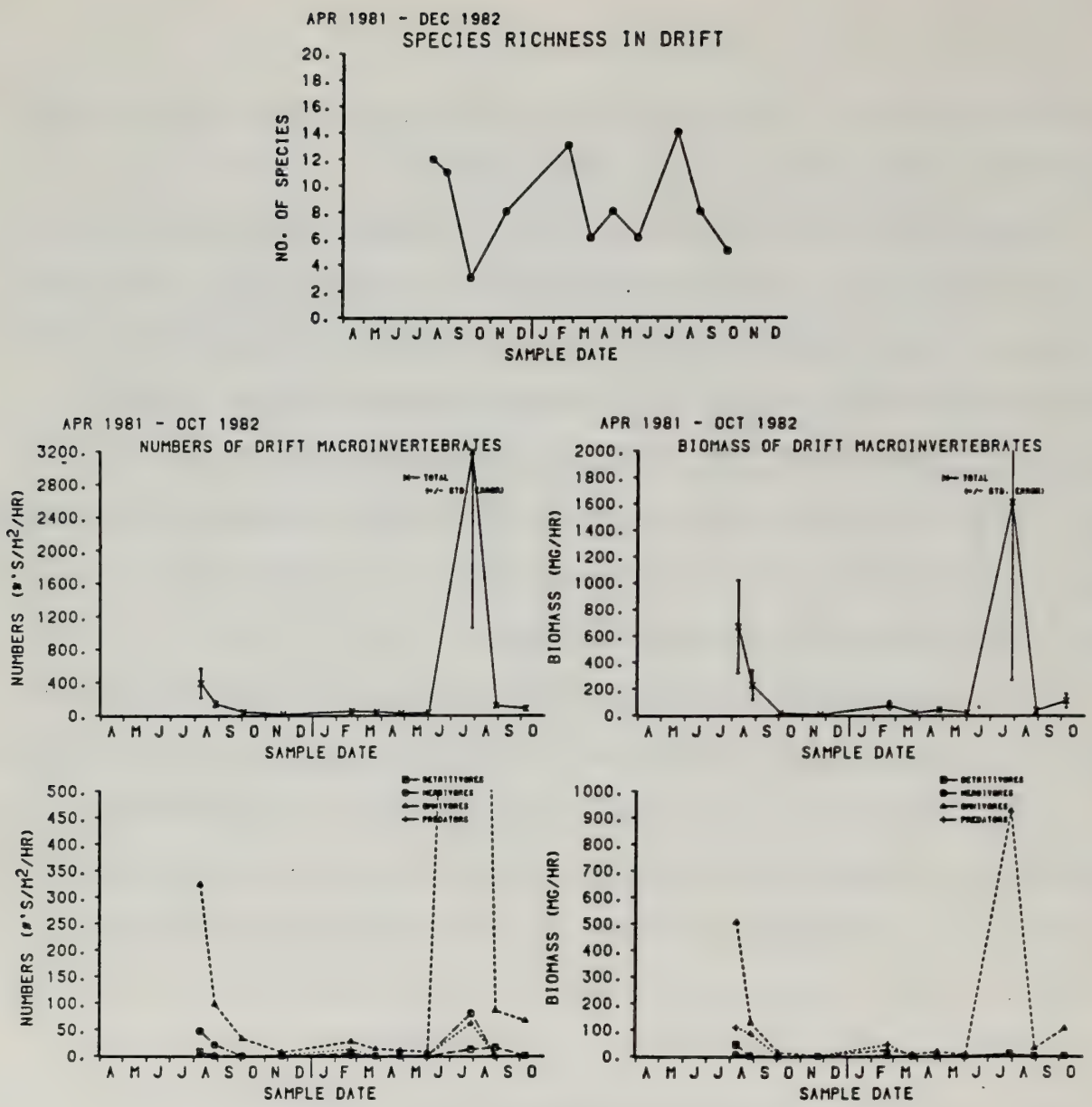


Figure 4.4-21 Species richness, numbers, and biomass of macroinvertebrates drifting per square meter of river cross-section in the White River at Ignatio Bridge and Southam Canyon from August, 1981 to October, 1982. Total numbers and numbers by functional group are presented.

biomass were high during upper basin runoff during 1982 but were apparently unaffected by storms. Functional groups reflected the distribution observed in the benthic populations.

4.4.6. Decomposers. The decomposers are important in the breakdown of organic matter through their metabolic activities which result in recycling of nutrients within the system. They are also an important energy source for many of the macroinvertebrates present in the White River. The rates of decay of leaf litter have been shown to respond to nutrients and depend upon the initial nutrient content (nitrogen and phosphorous) of material used (Elwood et al. 1981, Nelson 1982).

Figure 4.4-22 shows the relationship between decomposition rate and degree days of exposure in the White River. Data points shown do not include packs in the river after April, 1982. This was due to silting problems which occurred and reduced the decomposition rates for these packs markedly. Nelson (1982) found that silting and consequent anoxic conditions can drastically slow decomposition rates. These problems will be corrected during the 1983 program.

In general, decomposition rates were consistent and provided a good linear relationship with degree days. This relationship retains good potential as a monitoring parameter to characterize the decomposition process in the White River. Factors controlling this relationship will be investigated further during 1983 and the sampling methodology further refined to eliminate silting problems and bring this parameter to operational status.

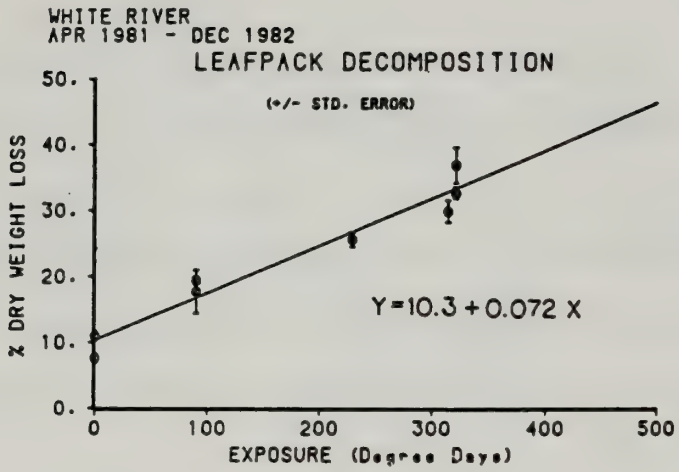


Figure 4.4-22 Leafpack decomposition for leafpacks at Transect WR18 in the White River. Data from leafpacks placed in the river during October thru December, 1981 and withdrawn during October, 1981-March, 1982.

4.5. SPECIAL STUDY-METALS IN THE WHITE RIVER

4.5.1. Introduction. In the aquatic environment, the concentrations of trace elements (ppb) are very low (Riley and Chester 1971) although higher concentrations can occur in rivers and lake systems associated with natural metal sources. These metal sources can substantially increase the heavy metal concentrations above levels normally encountered by the aquatic biocoenosis. Increases in both the essential (copper, zinc, iron, and other) and nonessential (lead, cadmium, mercury, arsenic, and other) trace metals may play an important role in regulating both the structure (Zanella 1982) and function (Medine and Porcella 1980) of the aquatic ecosystem. Furthermore, investigations of heavy metal pollution of the environment have shown that depending on the compartment studied (water, suspended matter, sediment) the results can lead to different interpretations regarding the toxicity of the metal concentrations measured with respect to the aquatic biota.

It has been suggested that where possible, any investigation of the impacts of heavy metal enrichment on the aquatic environment simultaneously determine the metal concentrations in as many trophic levels as possible (Forstner and Whittman 1981) and determine the functional responses of the ecosystem to elevated metal concentrations (Medine et al. 1980).

Previous studies (WRSOC 1974-1982) have indicated that the White River (Utah-Colorado) receives periodic heavy metal loads associated with storm events within its watershed. The White River system (Figure 4.5-1) drains approximately 10,240 km^2. This area has not been intensively developed,

although deposits of oil shale from the Green River formation (Piceance Creek and Unita Basins) are presently being mined but have not been retorted. The dominant surficial deposits within the drainage area are lacustrine sediments from Lake Unita (Paleocene Epoch) which consist of marlstones dominated by dolomite and calcite. These marlstones and their associated outcrops of oil shale appear to be the major source of these metals.

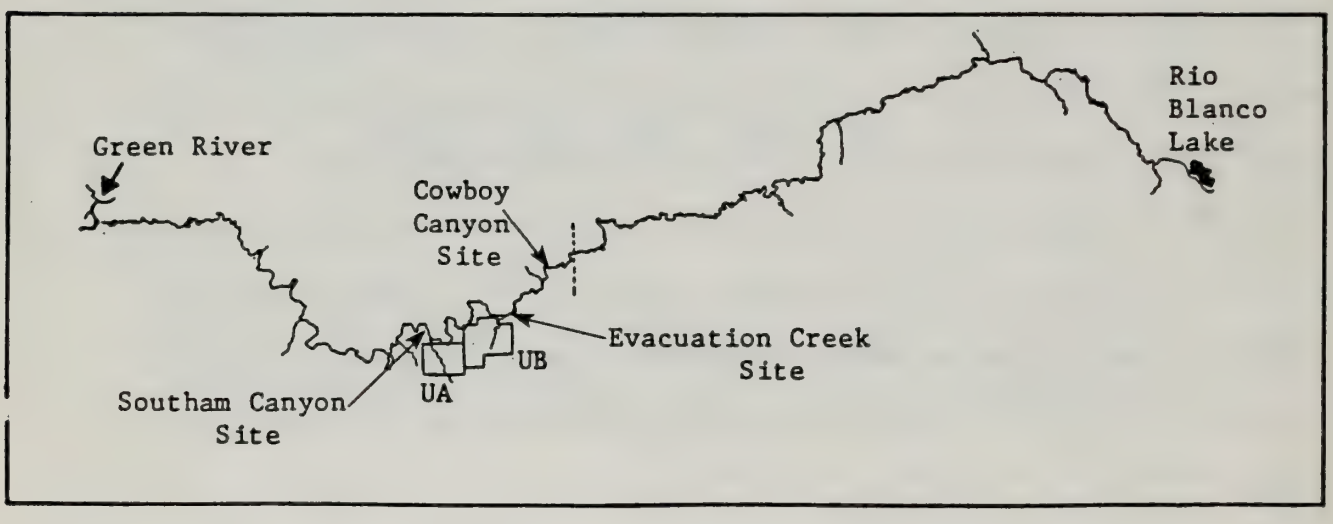


Figure 4.5-1 The location of the three sample sites on the White River (Utah - Colorado).

The naturally occurring periodic heavy metal loads provided a unique opportunity to investigate the response of an undisturbed aquatic ecosystem to elevated heavy metal concentrations. The objectives of this study were to:

- Determine the spatial distribution of selected heavy metals within

the trophic structure of the White River ecosystem.

- Define the baseline conditions within the White River prior to energy development (oil shale) within the drainage basin.

- Experimentally determine the functional response of the White River ecosystem to heavy metal loadings.

- Compare the results obtained from the White River to other natural and disturbed aquatic systems.

4.5.2. Materials and Methods. Three sites were selected along the middle course of the White River (Figure 4.5-1). The upstream site was in the White River at Cowboy Canyon and represented an area of the river above major outcrops of raw shale (Green River Formation). The intermediate site (in the White River below Evacuation Creek) was selected because of its location relative to the only perennial tributary along this section of the White River (four miles below Cowboy Canyon) and the presence of raw shale outcrops within the river itself. Previous studies have indicated that Evacuation Creek contained elevated levels of dissolved heavy metals during storm events (WRSOC 1974-1982). The lower site sampled (in the White River below Southam Canyon) was 10 miles downstream from the Evacuation Creek site and was adjacent to the Federal Lease Tracts Ua-Ub.

4.5.2.1. Field Methods. At each site, a rocky substrate area was selected for sample collections. Periphyton was scraped or picked from the rock substrates, placed in plastic bags, frozen, and returned to the laboratory. In a similar manner, rocks which contained a white precipitate were scraped in the field, placed in a plastic bag, frozen, and also returned to the laboratory. Macroinvertebrate samples were collected with a 1380 cm^2 modified Hess sampler (0.25 mm nitex mesh), frozen, and returned to the laboratory. Coarse detritus was collected concurrently with the macroinvertebrate samples. Substrate sediment samples were collected from the stream bottom and returned to the laboratory for drying and screening (<0.25 mm). Fish were collected by seining at each site, frozen, and returned to the laboratory for processing.

Production/respiration experiments were conducted at the Southam Canyon sites using 16 liter *in situ* clear recirculating plexiglass chambers developed by ERI (1981).

4.5.2.2. Laboratory Methods. Periphyton, precipitates, sediments, macroinvertebrates, detritus, and fish were separated, air dried, and homogenized. The solid samples were then analysed for their metal content.

The procedure involved a nitric acid and hydrogen peroxide digestion of the samples in a Tecam block digestor with a subsequent analysis using an Instrumentation Laboratory model 551 AA equipped with an IL 254 fastac autosampler and an IL 555 graphite furnace. Results indicated very little contamination from the reagents and the milli-q water used in the process. All glassware was thoroughly washed and then soaked overnight in 1:1 HCL and

rinsed three times with milli-q. Hot 1:1 nitric acid (ultra-pure) was added to each piece for an additional 24 hours soaking. Final preparation included three rinses with milli-q and one more soak with 1:4 HNO_3 and three final rinses with milli-q reagent grade water.

Copper and zinc were determined using the flame atomizer and the fastac autosampler due to the high levels in the liquid extract. Dried samples were weighed to the nearest 10^{-5}g prior to digestion.

4.5.3. Results

4.5.3.1. Trophic level metal accumulations. Seven separate compartments and six metals were determined at the three study sites in the White River. Table 4.5-1, which represents the mean $\pm$ S.E. for all sites sampled indicated the highest average metal contents were found in the macroinvertebrates for all metals except lead. Within this trophic level, Zn (275 ug/g) and Cu (92.1 ug/g) were found in the highest concentrations followed by Cr (72.5 ug/g), Ni (47.5 ug/g), Pb (20.4 ug/g), and Cd (12.9 ug/g). The trophic levels with the lowest concentrations for a given metal were: algae (Cu); fish (Pb, Cr, and Ni); and the carbonate precipitate (Zn and Cd).

A spatial comparison of the metal levels by trophic groups (Table 4.5-2; 4.5-3 and Figure 4.5-2) indicated that in the abiotic groups (carbonate precipitate and the fine-detritus sediment fraction), metal concentrations did not change with distance downstream. However, within the biological components of the ecosystem structure, change by sample site did occur. For example, the metal concentration in fish increased with distance downstream

Table 4.5-1 The heavy metal concentrations in the ecosystem components of the White River, Utah. Data collected on 4-25-82.

		Metal Concentrations ($\bar{x}$ ± S.E.; ug/g D.W.)					
Parameter	N	Cd	Cr	Cu	Pb	Ni	Zn
Water (ug/l) (1)		.136±.074	3.14±.95	2.65±.46	.64±.26	3.47±.79	14.0±4.9
Precipitate ($CaCO_3$)	(6)	.58±.39	38.5±18.2	16.9±3.6	10.3±3.84	19.9±6.2	23.9±7.1
Fine Detritus-sediments	(3)	1.05±.20	67.5±12.2	19.2±1.01	35.6±3.93	24.8±1.67	78.1±5.6
Coarse Detritus	(2)	2.48±.95	29.1±21.9	122.1±144	17.6±17.9	24.7±27.5	206±52
Algae	(4)	1.29±.21	58.6±16.0	14.6±9.8	22.4±3.6	23.9±8.5	83.2±48.3
Macroinvertebrates							
Predators	(2)	14.3±17.1	85.4±107	56.4±34	28.8±32	37.8±45	219±39
Coarse Part. Feeders	(1)	1.61	60.5	43.4	8.8	35.1	226
Total Macroinvertebrates	(6)	12.9±15.9	72.5±57.4	92.1±62.5	20.4±16.7	47.5±36.2	275±76.7
Fish							
Flannelmouth	(2)	1.67±0.1	13.89±13.5	12.4±1.9	3.63±0.31	6.01±5.0	118.1±26.7
Chubs	(5)	2.35±2.1	8.08±7.3	26.6±34	2.35±1.59	3.93±1.98	265±96.6
Blueheads	(2)	1.07±.43	5.17±1.6	16.4±2.62	2.52±.021	2.52±.48	73.5±.28
Speckled Dace	(1)	0.93	1.26	10.2	0.79	1.96	218
Total Fish	(11)	1.94±1.5	7.79±7.3	18.6±22.9	2.44±1.26	4.98±4.4	193±102

(1) mean dissolved metal concentrations from 1949-1982 (WRSOC 1982).

(for all metals sampled) whereas, the coarse detritus decreased with distance downstream for all metals except Cd. The algae remained approximately equal in concentrations with macroinvertebrates being split between metals. In macroinvertebrates, zinc, copper, and lead increased with distance downstream, while cadmium, nickle, and chrome decreased.

The concentration of metals within the fish trophic structure was further refined to include species with different food habits (Table 4.5-3). As noted above, average metal levels for this group of fish increased with distance downstream.

It is interesting to note that because of the large sample size available, two age groups of the roundtail chub (Gila robusta) were studied.

Table 4.5-2 The concentration of metals in various trophic categories in the White River on 4-25-82.

COWBOY CANYON

	Metal Concentration (ug/g dry weight)					
	Cd	Cr	Cu	Pb	Ni	Zn
Precipitate	.17±.12	40.9±20.3	12.9±1.8	5.71±0.27	24.6±6.0	26.2±4.4
Algae	--	--	--	--	--	--
Fine Detritus(sediment)	0.82	62.2	19.8	36.2	25.8	77.2
Coarse Detritus	--	--	--	--	--	--
Macroinvertebrates (All Species)	--	--	--	--	--	--
Fish (All Species)	1.51±0.44	4.35±1.03	9.9±1.5	1.99±0.46	5.11±2.75	154±25.5

BELOW EVACUATION CREEK

	Metal Concentration (ug/g dry weight)					
	Cd	Cr	Cu	Pb	Ni	Zn
Precipitate	0.99±0.2	43.5±14.6	17.8±0.4	11.9±1.6	20.2±0.6	29.2±0.6
Algae	1.05	46.2	17.4	27.0	17.9	54.1
Fine Detritus(sediment)	1.11	58.9	18.0	31.4	22.7	73.1
Coarse Detritus	1.80	44.6	203	30.2	44.2	243
Macroinvertebrates (All Species)	39.1	117.0	79.2	19.9	103.0	254
Fish (All Species)	1.54±0.26	5.17±0.76	13.8±2.2	1.75±0.37	3.13±1.07	185.5±57.4

SOUTHAM CANYON

	Metal Concentration (ug/g dry weight)					
	Cd	Cr	Cu	Pb	Ni	Zn
Precipitate	0.58±0.01	31.0±0.01	20.1±1.5	13.5±0.2	18.7±0.01	25.7±4.9
Algae	1.42	49.9	12.6	21.0	17.4	50.8
Fine Detritus(sediment)	1.22	81.6	19.7	39.2	25.8	84.2
Coarse Detritus	3.15	13.5	41.1	4.94	5.27	169
Macroinvertebrates (All Species)	9.06±5.19	64.6	206.0	23.5	55.7	335
Fish (All Species)	3.07±1.50	16.77±5.56	37.9±24.5	3.87±0.56	6.59±1.71	266.7±89.2

Table 4.5-3 The concentration of heavy metals in the various fish captured in the White River on 4-25-82.

			Metal Concentrations (ug/g dry weight)					
Location	Fish Species	N	Cd	Cr	Cu	Pb	Ni	Zn
Cowboy Canyon								
	Flannelmouth sucker	4	1.60	4.29	11.0	3.41	2.44	137.0
	Bluehead sucker	2	0.76	4.03	14.5	2.53	2.18	73.3
	Roundtail chub[1]	3	1.07	4.37	8.1	1.23	2.91	143.0
	Speckled dace	2	0.93	1.26	10.2	0.79	1.96	218.0
Below Evacuation Creek								
	Bluehead sucker	3	1.37	6.30	18.2	2.50	2.86	73.7
	Roundtail chub[1]	14	2.06	6.01	12.2	1.91	5.12	264.0
	Roundtail chub[2]	7	1.19	3.21	11.1	0.86	1.43	219.0
Southam Canyon								
	Flannelmouth sucker	4	1.75	23.5	13.8	3.85	9.58	99.2
	Roundtail chub[1]	26	1.40	5.73	12.9	2.93	3.63	297.0
	Roundtail chub[2]	1	6.07	21.1	87.0	4.84	6.56	404.0

[1] size range (45-70 mm)
[2] size range (73-200 mm)

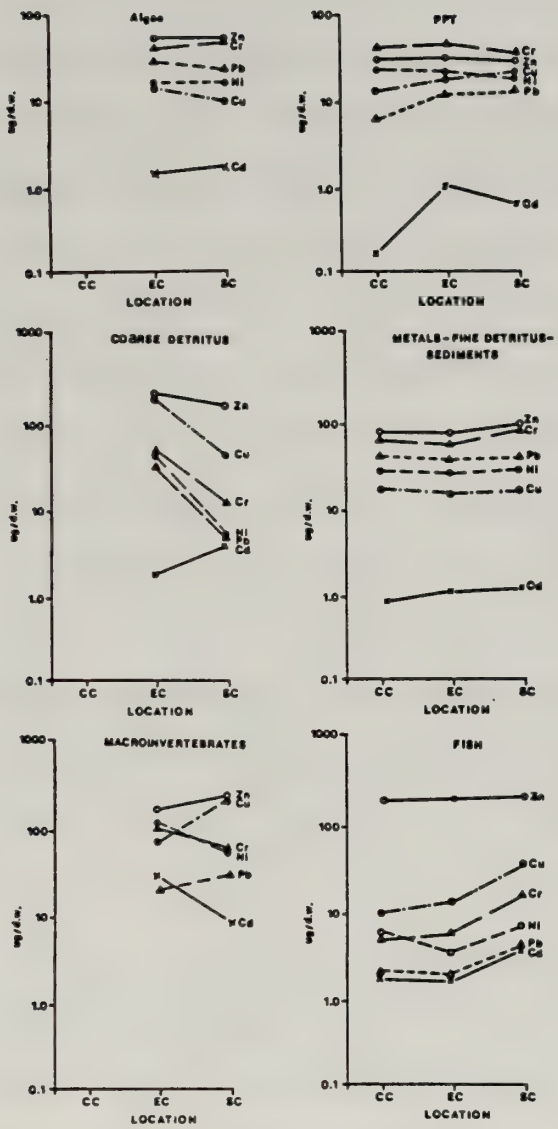


Figure 4.5-2 The concentration of heavy metals (ug/g d.w.) in each compartment studied in the White River. CC =Cowboy Canyon Site, EC = Evacuation Creek Site, SC = Southam Canyon Site.

The smallest size class (45-70 mm) increased in metal concentrations when the Cowboy Canyon and Evacuation Creek sites were compared. This same size group of fish captured at the downstream site (Southam Canyon) had intermediate metal concentrations compared to the Evacuation Creek and Cowboy Canyon. The adult fish (73-200 mm) captured at Southam Canyon had increased metal contents 2-8 times greater than fish captured at the Evacuation Creek site.

4.5.3.2. In situ production/respiration studies. Two separate in situ production/respiration experiments were conducted in the White River at the Southam Canyon site. The first experiment (P/R #1) was conducted between 6-30-82 and 7-2-82 and corresponded to upper basin runoff (Figure 4.5-3). During this time period conductivities (380 umohs/cm) were at their lowest and total suspended solids are at their highest (1298 mg/l) levels (Figure 4.5-4). During the control run (first 24 hours) net production, respiration, and gross production (mg O_2/m^2/day) were determined for the three identical chambers. At the beginning of the second day, a low level of copper (10 ug/l), high level of copper (50 ug/l), and a spent oil shale leachate (which increased the conductivity in the chamber 30 umohs/cm) was added to each chamber. The results (Table 4.5-4) indicated that the higher the copper concentration added, the greater the stimulation of net (158%) and gross (131%) production when compared to the control runs. Respiration was inhibited by the presence of these metal concentrations. Spent shale leachate had the greatest stimulation in net production (230%), respiration (117%), and gross production (182%). Dissolved metals were determined in the White River, initial concentrations in the P/R chambers, one hour after

start, and 24 hours after start. These concentrations can be seen in Table 4.5-5. These data indicate that copper and zinc were rapidly removed from solution within one hour after addition, whereas, chrome increased in concentration. The major mechanism was believed to be the adsorption and desorption from the large quantity of suspended sediments. Further investigations are being conducted on this mechanism of metal removal.

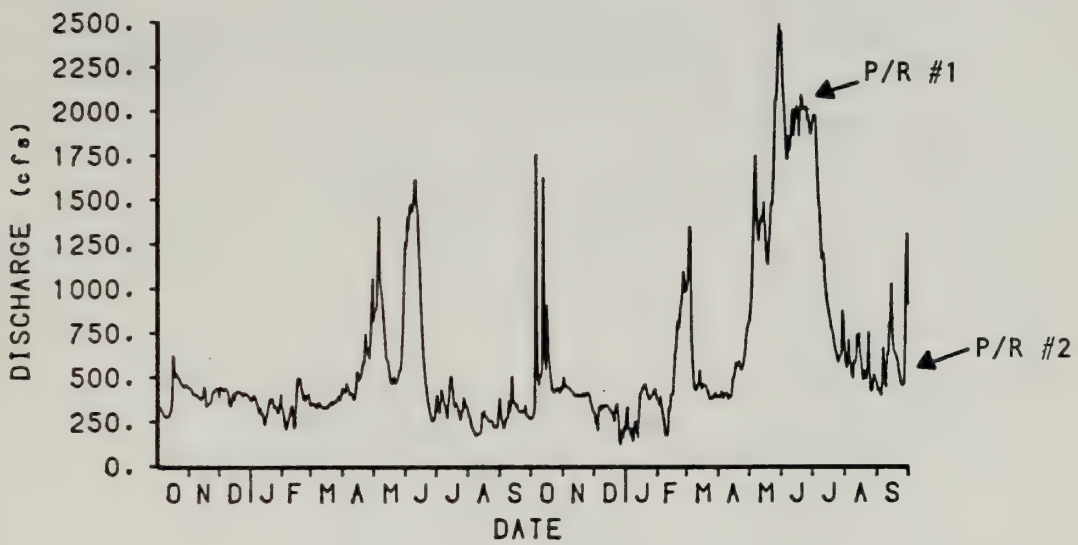


Figure 4.5-3 The discharge of the White River near Asphalt Wash (near Southam Canyon) during 1981 and 1982. Time periods for the two P/R experiments are given (6-30-82 and 11-3-82).

A second <u>in situ</u> production/respiration experiment (P/R #2) was conducted during a baseflow period (11-3-82 to 11-5-82). During this time period conductivities were at their highest (610 umohs/cm) and total

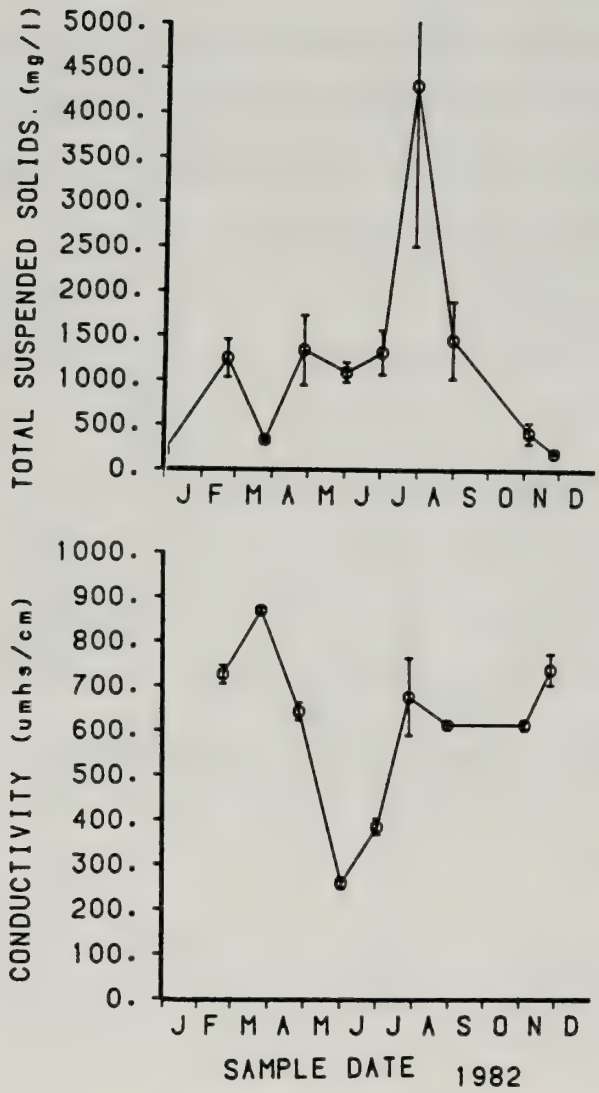


Figure 4.5-4 The conductivities (umohs/cm) and total suspended solids (ug/l) in the White River at Southam Canyon during the study period in 1982.

Table 4.5-4 The net production, respiration, and gross production estimates from the control and treatment chambers in the White River, Utah. Experiments were conducted between 6-30-82 and 7-2-82.

Control Run (mg O_2/m^2/day)				With Additions (mg O_2/m^2/day)		
Net	Respiration	Gross	Treatments	Net(%)*	Respiration(%)	Gross(%)
919	486	1494	#3 Low Cu^{++}	1456(158%)	418 (86%)	1951(131%)
610	366	1044	#5 High Cu^{++}	977(160%)	268 (73%)	1295(124%)
423	318	741	#8 Oil Shale Leachate	976(230%)	371 (117%)	1347(182%)

*% - represents the % of the control, with the control being expressed as the previous days' production-respiration experiment. 100% indicates that the control and treatments were equal.

Table 4.5-5 The soluble concentrations of Cu^{+2}, Cr^{+2}, and Zn^{+2} in the experimental production/respiration chambers in the White River between 6-30-82 and 7-2-82.

	Soluble Metal Concentrations (ug/l)								
	Cu^{++}(ug/l)			Cr^{++}(ug/l)			Zn^{++}(ug/l)		
Treatment	Initial(2)	1hr	24hrs	Initial(2)	1hr	24hrs	Initial(2)	1hr	24hrs
Control (1)	--	3.4	7.1	--	10.5	8.1	--	5.1	10.2
Low Cu^{++}	12.0	8.1	11.0	8.8	16.8	13.5	25.1	5.9	8.3
High Cu^{++}	52.0	22.6	23.2	8.8	21.5	17.5	25.1	14.7	7.2
Spent Oil Shale Leachate	--	2.2	7.3	--	9.0	6.8	--	14.1	6.0
White River	2.0	--	2.2	6.8	--	7.2	5.1	--	7.1

(1) mean values for the control run (previous days P/R experiment)
(2) calculated by known mass addition and chamber volumes

suspended solids were at their lowest concentrations (400 mg/l). The experimental procedure was the same as the previous experiment except for different treatments. During this experiment, four chambers were used with the following treatments: (1) no additions, (2) EDTA ($5x10^{-7}$ M), (3) low metal additions, and (4) high metal additions. The results of the control run (first 24 hours) and the experimental run with additions can be seen in Table 4.5-6. EDTA and the control chamber had no significant differences. Low metal additions stimulated net production, gross production, and respiration, whereas, high metals inhibited net production and stimulated respiration. The metal concentrations (Pb, Cu, and Zn) were reduced within the chambers during the 24 hours of the experiment from the initial levels (Table 4.5-7). Pb was reduced to below detectable levels within 8 hours after the start of the experiment.

4.5.4. Discussion. As noted in the previous section, one of the major objectives of this study was to determine the spatial and trophic-level distribution of selected heavy metals within the White River ecosystem. Previous investigations have noted that certain physical-chemical characteristics of a water body can substantially affect the metal ion concentrations within the water and therefore, the subsequent effect of the metal upon organisms (Figure 4.5-5). Dissolved oxygen and temperature (Lloyd 1965), pH (Whitley 1968), redox potential (Reinhart and Forstner 1976), hardness (Schweiger 1956), organics-metal ion interactions (Sprague 1968), complexation (Brown and Shaw 1974), and the chemical characteristics of the

Table 4.5-6 The net production, respiration and gross production estimates from the control and treatment chambers in the White River, Utah. Experiments were conducted between 11-3-82 and 11-5-82.

Control Run (mg O_2/m^2/day				With Additions (mg O_2/m^2/day		
Net	Respiration	Gross	Treatments	Net(%)*	Respiration(%)	Gross(%)
810	317	1036	#1 No Additions	951(117%)	317 (100%)	1177(114%)
647	306	867	#2 EDTA	768(119%)	330 (109%)	1004(116%)
741	298	954	#3 Low Metal	964(130%)	304 (102%)	1181(123%)
354	165	453	#4 High Metal	311(88%)	237 (144%)	453(100%)

*% - represents the % of the control with the control being expressed as the previous days production-respiration experiment. 100% indicates that the control and treatments were equal.

Table 4.5-7 The soluble concentrations of Pb, Cu, and Zn in the experimental production/respiration chambers in the White River, Utah between 11-3-82 and 11-5-82.

Soluble Metal Concentrations (ug/l)

Treatment	Pb^{+2}(ug/l)			Cu^{+2}(ug/l)			Zn^{+2}(ug/l)		
	Initial	8hrs	24hrs	Initial	8hrs	24hrs	Initial	8hrs	24hrs
No Additions	1.0	<0.5	<0.5	7.0	7.0	7.6	25.0	11.5	10.3
EDTA	1.0	<0.5	<0.5	7.0	5.6	4.6	25.0	11.0	9.6
Low Metals	6.0	<0.5	<0.5	32.0	14.0	13.0	75.0	22.0	13.2
High Metals	21.0	4.5	<0.5	107.0	30.0	36.0	225.0	54.0	30.5

individual metal species (Stumm and Morgan 1970) have been considered to be dominant factors in determining the effect of heavy metals on organisms. Furthermore, several studies have noted that biotic factors may play an important role in determining the response of an aquatic community to heavy metal enrichment. Factors, such as the organisms' life cycles (Lovett et al 1972), seasonal variations induced by primary producers (Morris 1971), contamination of food (Flegal and Martin 1977), and the mobility of the organism (Nisimura 1974) have been shown to be important. It is believed that the observed concentrations of metals in the abiotic and biotic components of the White River ecosystem are the result of many, if not all of the above factors. A specific discussion relative to each compartment will further investigate these possible mechanisms.

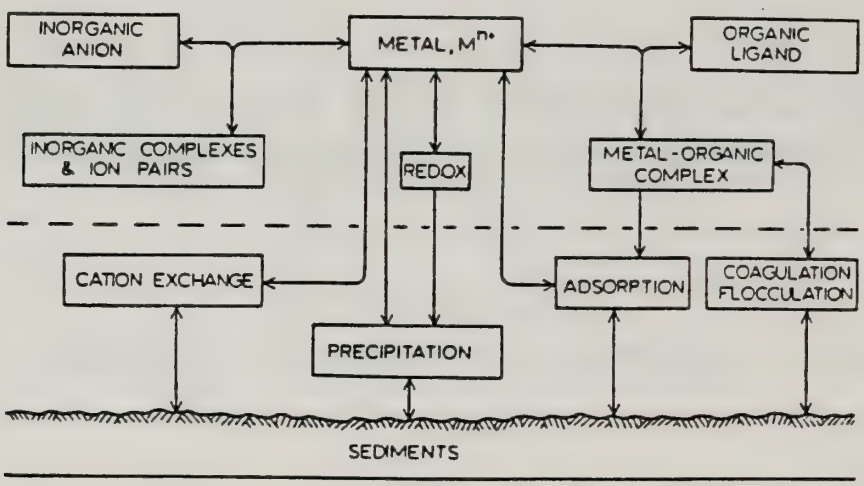


Figure 4.5-5 The natural phenomena which may affect the concentrations of heavy metals in natural environments.

4.5.4.1. Inorganic Environment (Calcium Carbonate and Fine Detritus Sediments). The coprecipitation or adsorption of trace metals with calcium carbonate has been documented in the literature (Patchineelam 1975). In the White River, the $CaCO_3$ precipitate contained substantial amounts of metals (Table 4.5-1). Chrome was in the highest concentration of the metals studied while cadmium was the least concentrated. A further inspection of the fine detritus inorganic sediments (which also contained $CaCO_3$ particles as well as other minerals) indicated the same pattern. The magnitude of the metal concentrations in this inorganic phase (Table 4.5-1) when compared to literature values (Table 4.5-8) indicate that chrome and nickel were in concentrations equal to or above those in contaminated systems. Cadmium and copper, although higher than background values were not in concentrations equal to contaminated river sediments. Lead and zinc were equal to background concentrations from other uncontaminated systems.

In Table 4.5-9, the concentration factors (water to sediments) based upon the average dissolved metal concentrations in the White River from 1949-1982 (WRSUC 1982) matched the sequence of divalent metal concentrations (Pb>Cu>Ni>Zn>Cd) found by Mitchell (1964) and Reynolds (1935). It appears that Pb, which had the highest concentration factor in the sediments, and lowest concentration in the water, has the ability to preferentially compete for exchange sites on the sediment clays and desorb other metals such as Cd and Zn (Soong 1974). The general sequence in order of decreasing ability to exchange is Pb>Cr>Cu>Ni>Zn>Cd. This represents the same sequence observed in the concentration factors (Table 4.5-9).

Table 4.5-8 The concentrations of Cd, Cr, Cu, Pb, Ni, and Zn for various components of the aquatic ecosystem from selected studies.

Ecosystem Site	Geographical Location	Metal Concentration ug/g dry weight						Reference
		Cd	Cr	Cu	Pb	Ni	Zn	
Inorganic phases								
Sediments	Menominee River (Michigan)							
	background	0.1	10.5	10.0	143	8.2	124	Lee et al. (1982)
	contaminated	9.3	23.7	37.0	315	19.9	230	
Sediments	River Etherow(England)							
	background	2.4	9.6	10.0	54	--	74.0	Say et al. (1981)
	contaminated	23.0	99.6	72.0	200	--	4960	
Sediments	Swiss Rivers							
	background	~0.3	--	--	~50	--	~75.0	Vernet et al.
	contaminated	≤ 9	--	--	100-300	--	225-750	(1977)
Sediments	Lake Powell							
	background	2.55	19.2	--	60.0	--	12.5	Medine & Porcella
	contaminated(lab)	4.60	42.0	--	104.0	--	266	(1980)
Organic phases (periphyton)								
Cladophora	Vermillion River (Illinois)							
	background	--	--	--	14.9	46	--	Leland and McNurney
	contaminated	--	--	--	347	265	--	(1974)
Cladophora	Lake Ontario							
	background	1.4	--	6.4	12.2	--	8.2	Keeney et al.
	contaminated	3.9	--	7.2	9.5	--	23.7	(1976)
Cladophora	Leine River/FRG							
	background	0.29	--	9.1	5.2	11.9	62	Abo-Rady (1977)
	contaminated	0.94	--	23.0	49.2	23.8	190	
Organic phase (macroinvertebrates)								
Asellus	Elsenz River (F.D.R.)							
	background	0.47	--	8.64	2.69	--	119	Prosi (1977)
	contaminated	2.97	--	19.91	16.50	--	203	
Brachycentrus	Sacramento River (California)							
	background	< 2.0	--	159	--	--	92	Zanella (1982)
	contaminated	5.8	--	155	--	--	682	
Hydropsyche	Sacramento River (California)							
	background	<2.0	--	168	--	--	178	Zanella (1982)
	contaminated	5.5	--	241	--	--	1096	
Gammarus	River Werra and Weser	0.18-0.77						Zauke (1982)
Organic phase (fish)								
Blue gill	Skinface Pond (So. Carolina)	--	--	2.15	1.10	--	142	Wiener and Giesy
Warmouth	Skinface Pond (So. Carolina)	--	--	2.04	0.80	--	103	(1979)
Largemouth bass	Skinface Pond (So. Carolina)	--	--	1.88	0.50	--	75	
Redfin pickerel	Skinface Pond (So. Carolina)	--	--	2.77	1.10	--	216	
Lake chubsucker	Skinface Pond (So. Carolina)	--	--	2.64	0.40	--	79	
Shorthorn sculpin	Strathcona Sound (Northwest Territories)	1.0-1.6	--	1.6-9.9	0.1-1.2	--	28-100	Bohn and Fallis (1978)
Artic Char	Strathcona Sound(Northwest Territories)	1.6-2.3	--	1.1-4.2	0.2-0.5	--	14-33	

Table 4.5-9 The concentration factors from water into each major component of the White River Ecosystem. Data collected on 4-24-82.

	Concentration Factors from Water ($x10^4$)				
Metal	Inorganic	Organic	Macro-invertebrates	Fish	Highest → Lowest
Ni	0.58	0.70	1.36	0.17	M > O > I > F
Cr	1.20	1.64	2.30	0.25	M > O > I > F
Cd	0.42	1.17	9.50	1.42	M > F > O > I
Pb	1.60	3.93	3.18	0.38	O > M > I > F
Cu	0.64	1.95	3.50	0.70	M > O > F > I
Zn	0.17	0.88	1.96	1.40	M > F > O > I

Highest	Pb	Pb	Cd	Cd
↓	Cr	Cu	Cu	Zn
	Cu	Cr	Pb	Cu
	Ni	Cd	Cr	Pb
	Cd	Ni	Zn	Cr
Lowest	Zn	Zn	Ni	Ni

4.5.4.2. Organics-Allochthonous Course Detritus. The passive movement of heavy metals onto detrital organics by adsorption has been investigated by Rashid (1974) and Jonasson (1977). In general, the sequence of highest to lowest concentration factors, based upon literature values are: Pb>Cu>Cd>Ni>Zn.

This sequence corresponds to the observed values from the White River (Table 4.5-9) for the coarse detritus-organic phase. The similarities in these two sequences may indicate that the concentration of metals in this organic compartment may be the result of the dissolved metal concentrations and the adsorption ability and/or complex stability of the individual metal species.

4.5.4.3. Organics - periphyton. Aquatic organisms have a requirement for certain essential metals (Cu, Zn, and others), while other metals (Cd, Cr, Pb, and Ni) are considered nonessential. Recent studies, (Davis 1973, Vancutsem and Gillet 1982, Harding and Whitton 1981) have shown that the uptake of certain heavy metals by aquatic plants was initially a passive process of adsorption onto the cell walls. The actual uptake was controlled by the rate of diffusion into the cell. The concentration of metals in the periphyton (Cladophora) from the White River indicated that all the metals studied were higher than previously determined background levels (Table 4.5-8). In several cases (Abo-Rady 1977, Kenney et al. 1976) the background concentrations in the White River were higher than contaminated sites. It should be noted, however, that Leland and McNurney (1974) reported concentrations of Ni and Pb in Cladophora taken from a contaminated section

of the Vermillion River that were 10 times higher than those reported in this study. The concentration factors (Table 4.5-9) for the organic phase are comparable to other literature values (Medine and Porcella 1980). As noted above the sequence of decreasing concentration factors corresponded to the sequence of decreasing passive adsorptive abilities of the specific metals onto organic materials.

4.5.4.4. Organic phase - macroinvertebrates. Unlike the plants which were previously discussed, there are several ways in which heavy metals can be introduced into organisms. In general, there are three basic machanisms: (1) direct uptake via skin or gills, (2) adsorption onto body tissues, and (3) from food.

It should be noted that the macroinvertebrate trophic level in this study, contained a variety of organisms with different food sources. Detritivores, herbivores, omnivores, and carnivores were included. However, in each case the food types eaten by these macroinvertebrates contained significantly higher levels of metals when compared to the water. Furthermore, several of the dominant species from this group were constantly in direct contact with the sediments (where elevated metal concentrations were detected). It was believed that because of these factors and the apparent lack of a homeostatic controlling mechanism, this trophic group had the highest metal concentration factor (except for Pb) relative to the water (Table 4.5-9). These results are consistent with the findings of Bryan and Hummerstone (1971) and Ayling (1974). Cadmium, which had the highest concentration factor, was found to be substantially higher than reported

literature values for macroinvertebrates in contaminated rivers. Zinc was found to be above background levels whereas Cr, Cu, Pb, and Ni are comparable to other background values.

4.5.4.5. Organics - Fish. In comparison to literature values (Table 4.5-8), the fish in the White River contained substantially higher levels of all metals when compared to other uncontaminated areas. Experimental studies have indicated that in most cases the rates of metal uptake in fish have been related to the concentrations in the water (Pentreath 1973) and (more importantly) to the metal concentrations in the food (Hoss 1964, Renfro et al. 1974, Delisle et al. 1975). However, numerous studies have shown that there is no certainty that the concentrations in the fish will reflect those of the environment regardless of the metal source (water or food). This is especially true for such metals as copper and zinc where excretion or some sort of regulatory mechanism has been shown (Mount 1964; Brung, Leonard, and McKim 1973; Fromm and Stokes 1962). Non-essential metals such as Cd, Ni, Cr, and Pb are not as well regulated and can accumulate to levels 10^3 to 10^4 times the levels observed in the water (Table 4.5-9).

It was previously noted that the concentration of all metals increased in the overall fish community with distance downstream (Figure 4.5-2). It was believed that Evacuation Creek was a major source for several of the metal species found to be present at the Evacuation Creek and Southam Canyon sites in the White River (Table 4.5-10).

4.5.4.6. Trophic Level Accumulations. There are conflicting results from studies which center around the concept of food chain enrichment with

Table 4.5-10 The maximum observed concentrations of selected metals in Evacuation Creek and the White River. Literature Values (1949-1982).

	Metal Concentrations (ug/l)					
	Cd	Cr	Cu	Pb	Ni	Zn
Evacuation Creek (09306430)	1	30	600	4	9	110
White River (9306700)	1	10	45	5	12	130

heavy metals. The results presented here appear to agree with the finding of Enk and Mathis (1977). Figure 4.5-6 and Table 4.5-9 indicate that to a certain extent, metal concentrations within the trophic structure were accumulated above the major food sources. The major sequence in decreasing concentrations were: Macroinvertebrates>Detritus organics≥Inorganics≥Fish.

Although the various species of metals studied exhibited food chain enrichment to various degress, macroinvertebrates generally had the highest concentration and fish the least. The interrelationship between metal content in the surrounding environment (water, sediment, etc.) and the ability to bioregulate both essential and nonessential metals appears to be important regulating factors.

4.5.4.7. Adsorption-Desorption of Heavy Metals. The quantitative description of heavy metal adsorption and desorption has been and is currently an area of intensive research activity. It is generally understood that descriptions of metal pathways and speciation must necessarily include

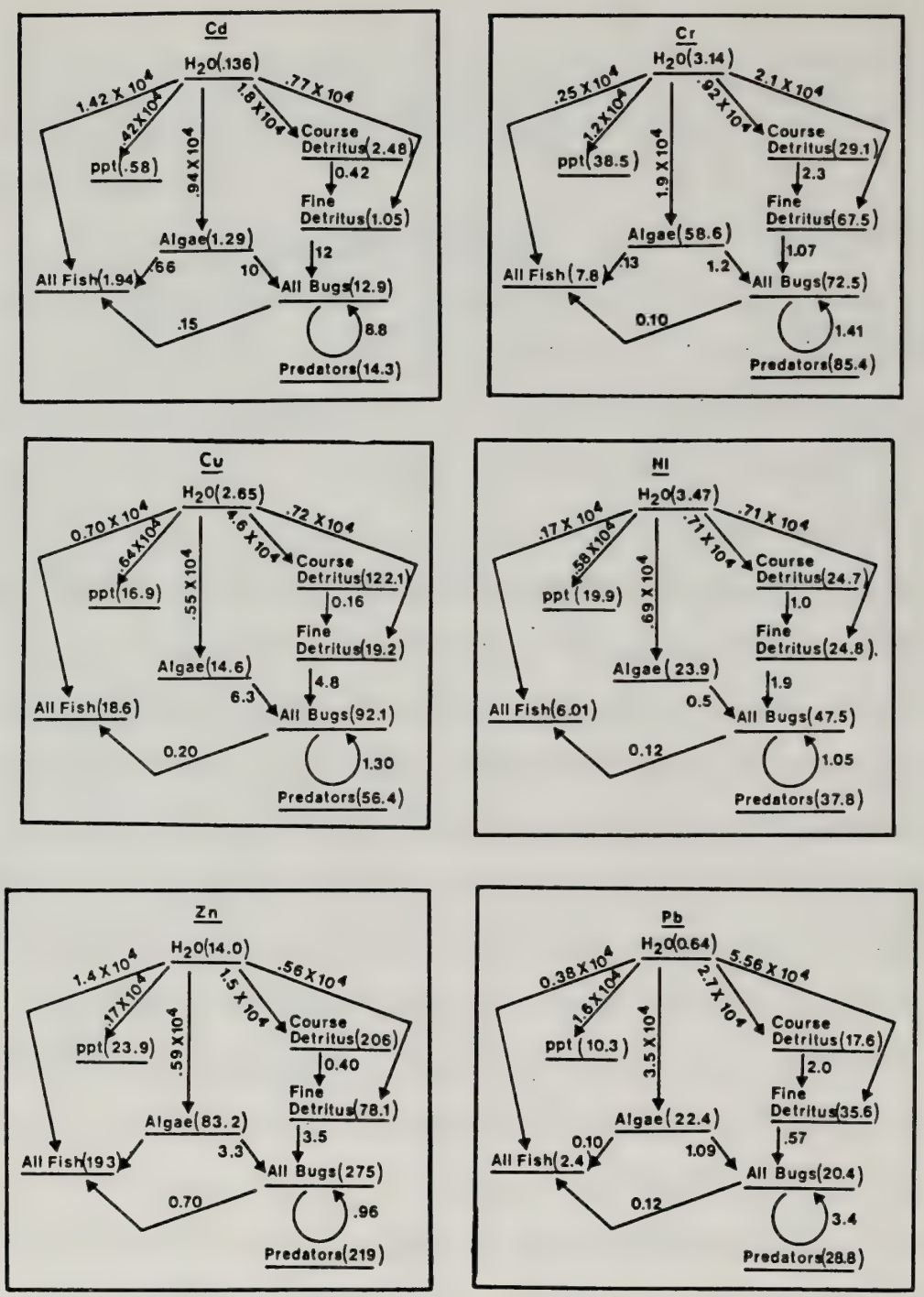


Figure 4.5-6 The trophic level accumulations for the selected heavy metals studied in the White River. Numbers in parenthesis ( ) represent ug/g d.w. While numbers by the arrows are concentration factors between compartments.

the role of adsorption in the regulation of metal concentrations. Heavy metal accumulation by sediments and suspended matter occurs by physical-chemical adsorption, biological uptake and by physical accumulation of metal enriched particulate matter through sedimentation. Physical-chemical adsorption on suspended particulates and sediment accumulation of metal enriched particulates appear to be the major mechanisms by which periodic metal loads are attenuated in the White River.

The difficulty in developing quantitative models to describe adsorption/desorption in natural environments is due to the complexity of natural sediments and particulates, the effect of inorganic and organic ligands upon adsorption, the metal species distribution, and other physical-chemical attributes of the environmental system (pH, adsorbent concentration, etc). To overcome some of this difficulty, adsorption studies using "model" surfaces (clays, Al_2O_3, $Fe[OH_3]$, MnO_2) have been performed and provided an important understanding of the mechanisms. A considerable amount of work has been reported on the adsorption of metals by clays (Jenne 1977, Farrah et al. 1980) although evidence indicates that clays exist as substrates coated with metal oxides or organic matter (Bourg, 1982).

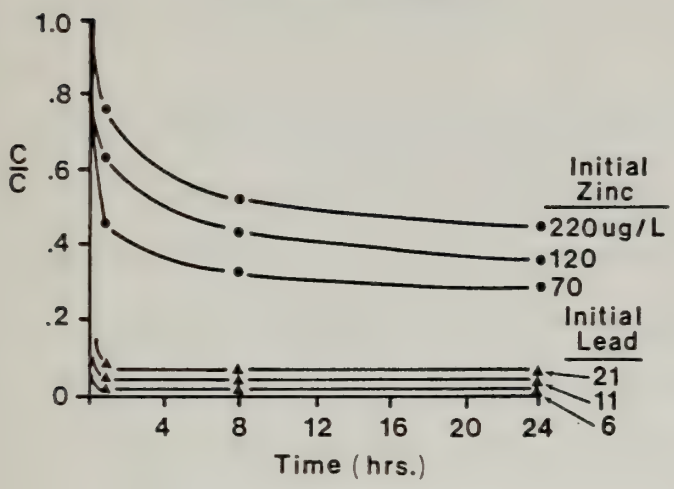
Additionally, work with metal oxides (Dempsey & Singer, 1980; Benjamin and Leckie, 1981; Elliott and Huang, 1979) has resulted in considerable advances in understanding metal uptake mechanisms. Complexation of metal ions by inorganic and organic ligands can have a considerable impact on the adsorption by solid surfaces, the result showing an enhancement, suppression or no effect upon metal adsorption (Benjamin and Leckie, 1981; Elliott and

Huang, 1980). Metal adsorption studies using real sediments (Brown, 1979; Sholkovitz and Copeland, 1981, Gardiner, 1974) can provide hints about potential adsorption mechanisms and statistical correlations between particular sediment parameters and the metal mass adsorbed, but cannot give detailed information on the operative mechanisms. It is clear that further work is necessary to quantitatively describe the adsorption process in natural systems.

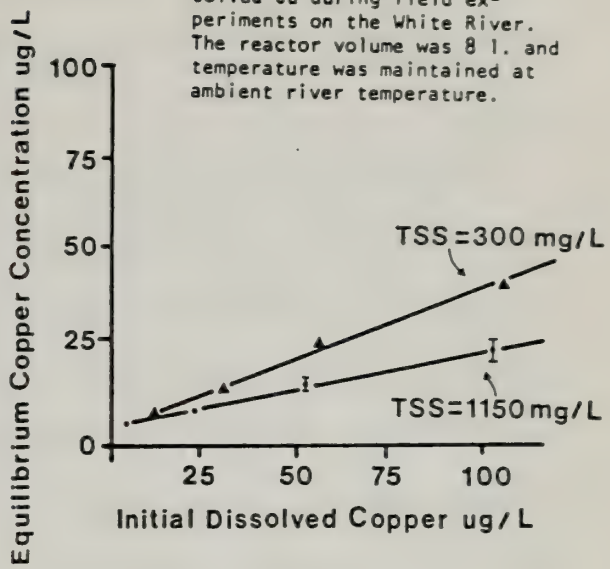
The adsorption of Cu, Zn, and Pb by suspended sediments in the White River was investigated using reaction chambers, natural water, and sediments during two distinct flow periods (Figure 4.5-7 [a-d]). The data indicated that removal was very rapid (<1hr.) and that particulate concentration and pH were important in determining equilibrium concentrations of metal. The sediments and suspended particulates of the White River, tributaries, and dry washes possess a complex mixture of inorganic and organic constitutents. Calculations using MINEQL (Westall et al., 1976) indicate supersaturation of $CaCO_3$, Fe $(OH)_3$, $Al(OH)_3$, and other minor solid phases of Zn, Cu, and Ni and indicates that the effect of carbonate and hydroxide solid phases may also be important attributes of the White River system.

4.5.4.8. Ecosystem Response and Metal Tolerance. Few studies have attempted to define the *in situ* response of aquatic ecosystems to an experimental metal load. Gachter (1979) attempted such a study in a lake ecosystem, while Medine et al. (1980) documented a laboratory ecosystem response to heavy metal loads. The *in situ* production/respiration experiments reported in this study have indicated that the White River

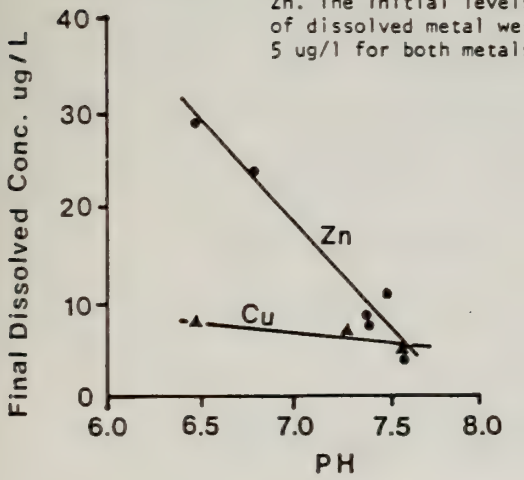
a) Adsorption vs. time for three levels of Pb and Zn during field experiments on the White River in Nov., 1982. Each reactor volume=8 liters.



c) The effect of initial copper and suspended solids on the 24 hr. equilibrium dissolved Cu during field experiments on the White River. The reactor volume was 8 l. and temperature was maintained at ambient river temperature.



b) The effect of pH on the equilibrium level of Cu and Zn during field experiments on the White River. Desorption was highly significant for Zn. The initial levels of dissolved metal were 5 ug/l for both metals.



d) The effect of initial zinc and suspended solids on the 24 hr. equilibrium dissolved Zn during field experiments on the White River. Temperature and volume as above.

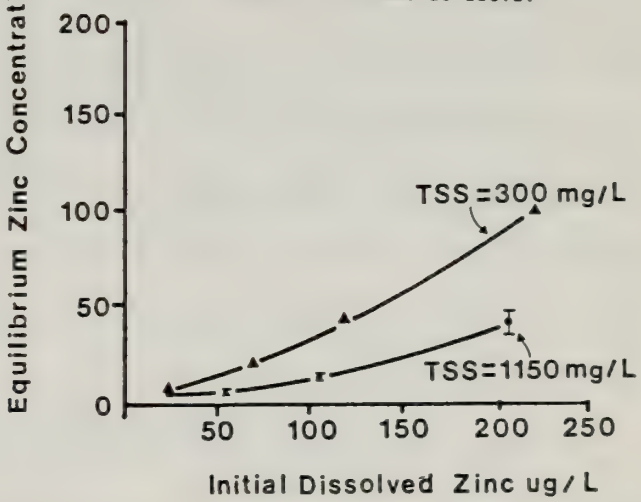


Figure 4.5-7 (a-d) The results of field experiments on metal adsorption on the White River conducted during November 1982.

ecosystem appears to be stimulated by the periodic input of heavy metals. The response of the river system appears to change depending upon the time of year.

The mechanisms by which the White River ecosystem has been able to adapt to these periodic natural metal loads is unknown. There are numerous examples in the literature where organisms have been shown to increase their tolerance to the toxic effects of some metals. Fish (Sinley et al. 1974), macroinvertebrates (Saliga and Ahsanullah 1973), and algae (Morris 1972) are several examples of this possible mechanism. It has been suggested that their tolerances may be genetically determined; however, the evidence at the present time is circumstantial (Bryan and Hummerstone 1973).

A second possible mechanism of adaptation may be the temporal distribution of organisms within this system. Zanella (1982) noted a change in species composition within the macroinvertebrate community structure over a 15 year period as a result of low level metal pollution. The two organisms described in that study were also found in the White River (Figure 4.5-8). Their distribution over time in the White River indicted that the more resistant species (Hydropsyche) was present when water quality was potentially at its worst (base flow conditions) . Whereas, the less resistant species was present during upper basin runoff when the best water quality conditions occurred.

A third possible mechanism, the adsorption and desorption of the soluble metals with suspended sediments, was investigated simultaneously with the P/R experiments (Medine et al. 1983). These data indicate that the suspended

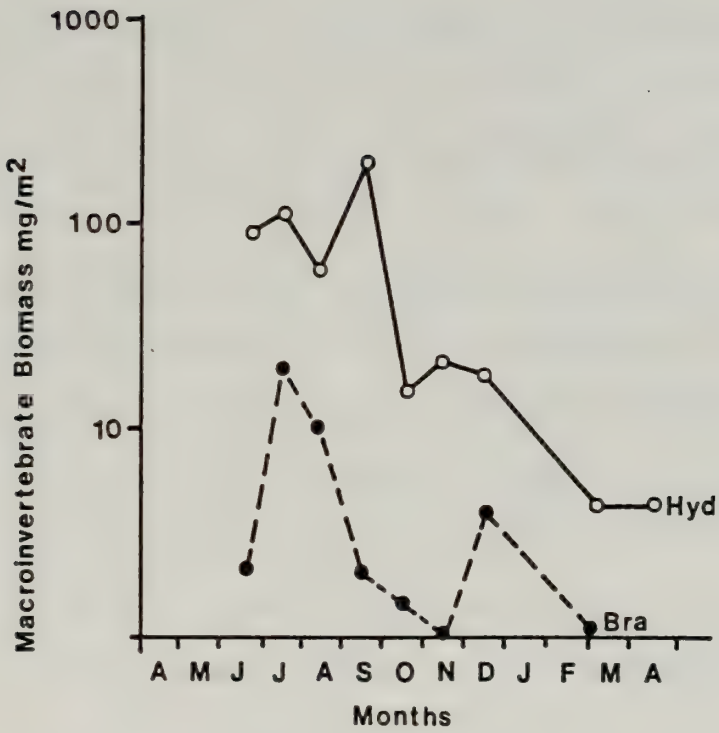


Figure 4.5-8 The biomass of two macroinvertebrate species in the White River during 1981 at the Evacuation Creek Site. BRA = Brachycentrus (non-tolerant); Hyd = Hydropsyche (tolerant)

sediments within the White River can substantially and rapidly reduce the concentrations of dissolved heavy metals. Adsorption of metals into the organic compartments (algae, course detritus) may also be an important factor in the removal of metals from solution. The consistant levels of metals in the inorganic (precipitate and fine sediments) and algae compartments with distance downstream (Figure 4.5-2) and similarities in the sequences of adsorption ability of the metals compared to the concentration factors, may indicate that adsorption-desorption can regulate the concentration of metals in the White River between storm events.

It is important to note, that although the White River maintains a diverse and productive ecosystem, the metal concentrations present within the trophic structure are elevated above literature background levels. The exact mechanisms (genetic shifts, organism tolerance, spatial and temporal seperation and the role of suspended sediments) by which this community can maintain its structure and function is unknown. Further investigation into the mechanism may allow the development of management alternatives for the restoration of anthropromorphically disturbed systems.

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TERRESTRIAL FAUNA

5.0 TERRESTRIAL FAUNA

5.1 INTRODUCTION

The terrestrial fauna of the Federal Prototype Oil Shale Tracts, Ua and Ub has been sampled since 1975. Sampling in 1982 represents the first year of operation of the monitoring program as described in the Environmental Monitoring Manual (WRSOC 1982a). As a result, sampling of some groups was less extensive than during the 1975-1981 baseline period. Other groups (referred to as Potential Parameters in the Monitoring Manual) were sampled for the first time in order to establish baseline information.

All sampling and analysis was conducted by Bio-Resources, Inc. under contract to WRSOC and was coordinated by Dr. C. Val Grant.

Five major groups of terrestrial fauna were emphasized during 1982: soil invertebrates, foliage invertebrates, reptiles, birds, and mammals. This section will describe the species composition and community characteristics of each group during 1982 and then compare these characteristics to the baseline period, 1975-1981. Significant changes in community characteristics are identified. These changes are compared to changes in environmental variables and potential impacts of human and natural disturbances to identify causes of the changes. Tract development activities during 1982 appear to have had little effect on wildlife except in the immediate vicinity of the construction sites.

5.2 SUMMARY

The terrestrial fauna on Tracts Ua and Ub was subjected to climatic extremes during 1982. Annual water-year precipitation (36.8 cm) was higher than in any of the previous 7 years while spring (April-June) precipitation was lower than all years except 1978 (Fig. 5.2-1). Erratic water availability combined with a very cool spring and beginning of summer resulted in significant changes in some faunal groups. None of the changes that were noted can be attributed to the road and plant site development that occurred in 1982.

Results for each group of species are summarized below.

5.2.1 Soil Invertebrates Total abundance, species richness, and species diversity of nematodes and microarthropods differed significantly among sampling sessions and were high during the cooler, wetter fall, winter, and early spring and low during the dry, hot summer. Habitats with deeper soils, Riparian and Greasewood, had higher nematode abundance, richness, and diversity. Microarthropods had highest abundance in Riparian but high richness and diversity on S-1 and J-5. Soil invertebrates were partitioned into 4 trophic groups: herbivores, detritivores, carnivores, and bacteriovores. Abundance of each trophic group followed the same pattern as total abundance, high in cool, wet months and low in hot, dry months. Comparisons between 1981 and 1982 indicates, in general, lower populations in summer 1982, apparently due to the drier conditions.

5.2.2 Foilage Invertebrates The foliage invertebrate studies in 1981 and 1982 have been conducted over seven months, in four vegetation types (nine transects), and for 10 hostplants. The observed patterns in abundance, biomass, species richness, and diversity can be explained by environmental factors such as temperature, precipitation, soil moisture, plant phenology,

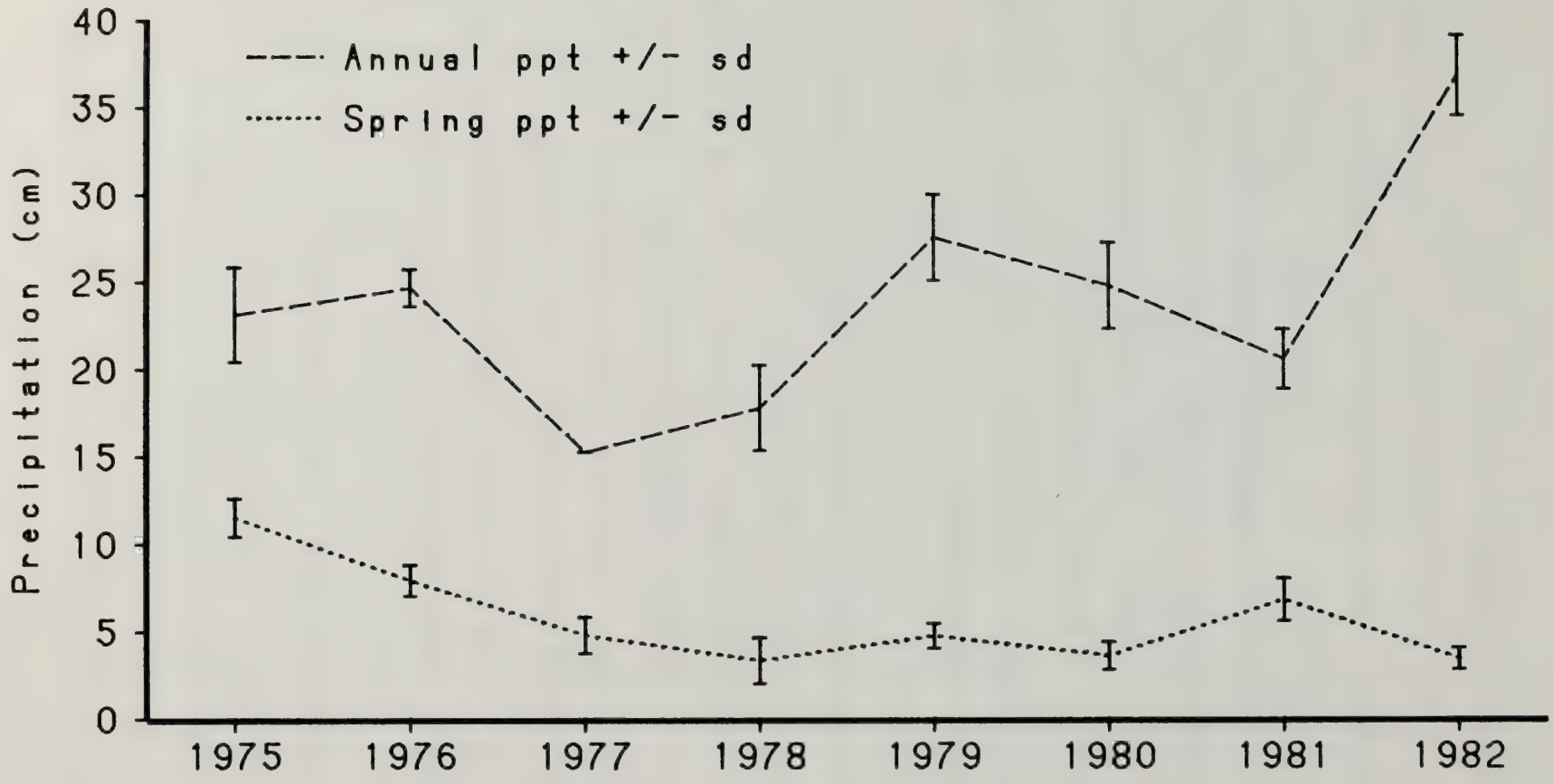


Fig. 5.2-1. Annual precipitation (water year) and spring precipitation (April-June) at Utah Oil Shale Tracts, Ua and Ub, from 1975 to 1982.

and plant production. The colder, wetter conditions in 1982, compared to 1981, were paralleled by a dramatic increase in foliage invertebrate abundance and richness but no noticeable increase in biomass. These increases occurred on all hostplants and in all vegetation types. Seasonal population peaks occurred later in 1982 than in 1981. Sticky-leaved rabbitbrush, rubber rabbitbrush, and big sagebrush had the highest abundance of invertebrates, followed in decreasing order by greasewood, shadscale, spiny hopsage, and spiny horsebrush. Riparian habitat had the greatest abundance of foliage invertebrates, followed in decreasing order by Greasewood, Juniper, and Shadscale habitats. Differences in foliage invertebrate abundance between years and vegetation types were consistant with differences in annual-plant biomass and soil moisture.

5.2.3 Amphibians and Reptiles Estimates of reptile populations made in June 1982 were compared to those of previous years. Lizard abundance in both the Greasewood and Shadscale habitats declined only slightly (12% and 7%, respectively) from 1981 abundances but abundance in Juniper declined 46%. These declines may be due to the wet fall, winter and cold spring in 1982. The Riparian habitat, on the other hand, recorded a 33% increase in lizard abundance, returning to a value within the 7-year, 95% confidence interval. Only one amphibian was observed in 1982.

5.2.4 Birds Bird populations (measured in community consuming biomass) in Greasewood, Juniper and Shadscale were lower in 1982 than in most previous years. In Riparian, consuming biomass was higher than in any previous year. In Greasewood, all three trophic groups (granivores, omnivores, and insectivores) declined between 1981 and 1982, the decline in insectivores being primarily due to a decline in ground-gleaning insectivores, the largest

insectivore guild in Greasewood. In Juniper, granivores and air-cruising insectivore declined. Bird consuming biomass in Shadscale as well as trophic group and guild composition, was similar to that in 1981. In Riparian the increase between 1981 and 1982 was caused by a dramatic increase in cliff swallows (Hirundo pyrrhonota), an air-cruising insectivore. Most other guilds in Riparian declined or remained the same. The low consuming biomass of most bird groups in 1982 can be attributed to the low spring precipitation and to presumed effect on food resources. High populations of cliff swallows may also be related to food availability, as high flows in the White River (from snowmelt) were prolonged, increasing habitat for insect production.

Eleven active and 47 inactive raptor nests were located in 1982. These included three active golden eagle (Aquila chrysaetos) nests, none of which were located within the boundaries of Ua and Ub. Twenty-four inactive golden eagle nests were found.

A February survey of the White River found 10 bald eagles (Haliaeetus leucocephalus) wintering in Riparian habitat adjacent to Ua and Ub.

Eleven species of waterfowl were found on the White River in April 1982. The most abundant species was Canada goose (Branta canadensis) which was most common at mile 12, between the site of the proposed White River Dam and Ignatio. Overall, waterfowl were most abundant between Ignatio and Hell's Hole Canyon.

5.2.5 Mammals Rodent density and biomass in 1982 maintained pre-1982 levels in all habitats except in Riparian. In Riparian, the movement of the trapping grid from R-1 and R-2 resulted in capture of more individuals of three species causing an increase in both density and biomass. Also, during 1982, montane voles (Microtus montanus), which were caught only once before

1982, had a population explosion becoming one of the most common vertebrates in Riparian habitat. Between 1981 and 1982 species diversity increased in Greasewood, Shadscale, and Juniper. In Greasewood and Juniper this was a result of an increase in the less abundant species and therefore a more even distribution of individuals among species. In Shadscale, two species were found which had not been recorded previously. These changes may be due to the heavy precipitation in fall 1981 resulting in abundant germination and growth of winter annuals, food resources for most rodents.

A cycle of population density with a period of about six years has been identified for desert cottontails (*Sylvilagus auduboni*). The factors that cause variability in environmental quality and thus cottontails are not as sensitive to changes in their environment as are some other small mammals.

Mule deer (*Odocoileus hemionus*) herds were found throughout the site during April and June. Sightings were in or near plant cover provided by juniper or the Riparian habitat. Most deer were observed during April and June.

5.3 PROGRAM DESCRIPTION

5.3.1 Objectives The objectives of the first year of the development monitoring program were to identify differences between the 1975-1981 baseline period and 1982 data. For differences that were identified, a secondary objective was to determine whether the changes were naturally caused or were related to construction or monitoring activities.

Data from 1982 were also used to evaluate some potential environmental parameters in order to assess their efficiencies for monitoring. As a result, several potential monitoring parameters were measured for the first time.

5.3.2 Sampling Locations Sampling locations are shown in Fig. 5.3-1. The nine transects shown were sampled for soil invertebrates, foliage invertebrates, reptiles, birds, and mammals. Rodent populations were sampled on nine trapping grids located near the transects.

In anticipation of future construction of the White River Dam, which will inundate one riparian sampling location (R-2), a new riparian transect and mammal-trapping grid (R-4) was established. R-4 is 500 m downstream and across the river from R-2. These two sites will be run concurrently until dam construction interferes with sampling R-2. These concurrent samples will allow us to establish the similarity of the wildlife at these two riparian sites.

5.3.3 Methods Methods for most sampling were described in the Monitoring Manual (WRSOC 1982a). Other methods employed are discussed below.

5.3.3.1 Soil Invertebrates The number of soil samples collected along each transect was decreased from 12 in 1981 to 6 in 1982. Analyses were done only for species that occurred in at least 12 soil samples. One-way Analysis of Variance was used to determine whether community abundance, richness, and

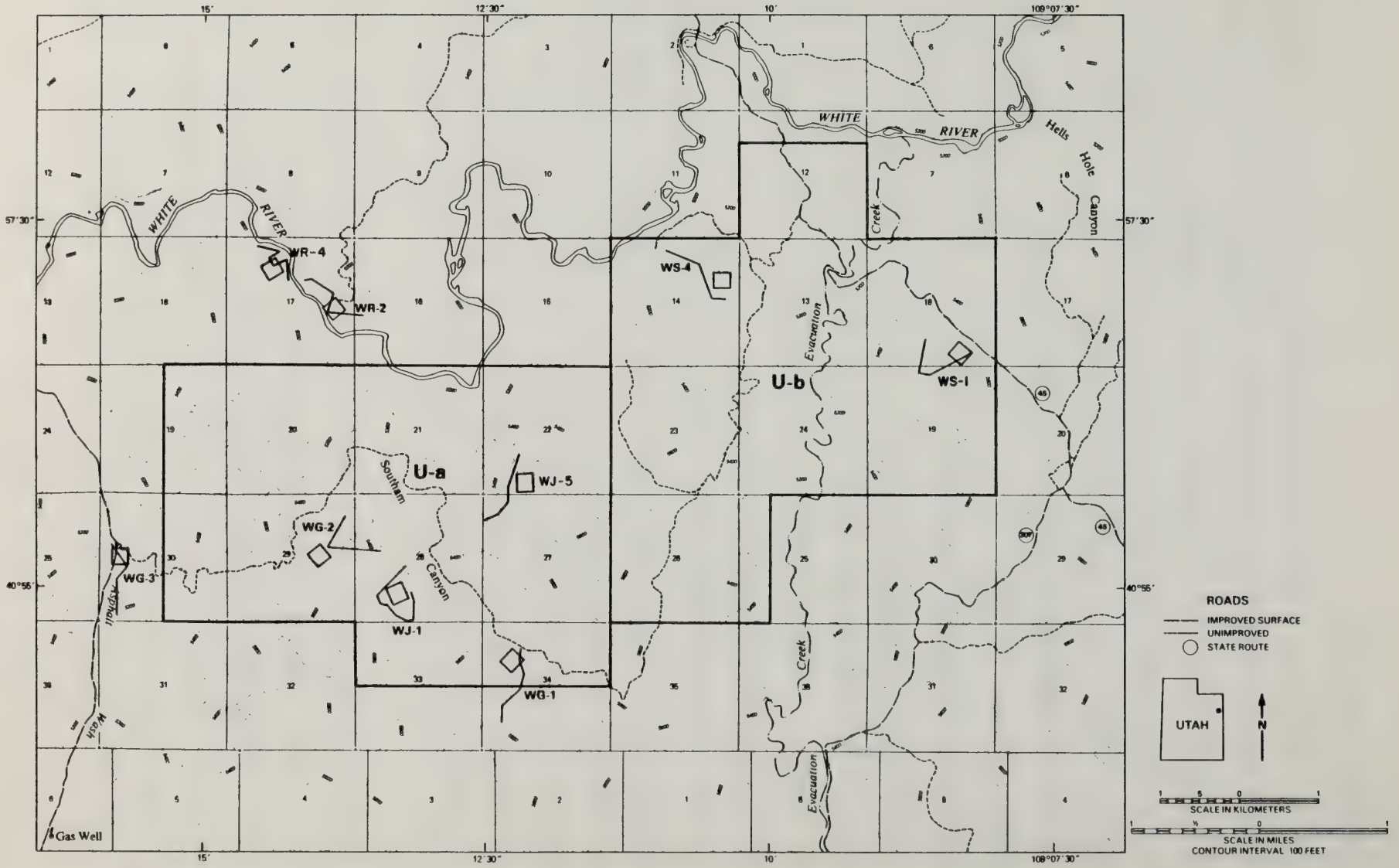


Fig. 5.3-1. Sampling locations on and near Tracts Ua and Ub. Habitat designations are WG, Greasewood; WJ, Juniper; WS, Shadscale; WR, Riparian. Solid lines are 1 km flushing transects, squares are rodent trapping grids.

diversity differed among months and transects. Two-way Analysis of Variance was used to determine whether trophic group densities differed among months and transects. A Least Significant Difference test was used to compare months and transects ; $\alpha = 0.05$.

5.3.3.2 Foliage Invertebrates Abundances were calculated for individual shrubs, and biomass data were collected for each hostplant within each transect. Family-level diversity was calculated for each hostplant within each transect. Sweep-net samples were compared to beating samples of big sagebrush on eight transects. The purpose of comparing the two sampling techniques was to attempt to improve the accuracy and precision of the sampling. It was hoped that beating would capture a greater percentage of the invertebrates on a shrub and reduce the sample variance.

Data were analyzed with Analysis of Variance, using a log (X+1) transformation to normalize the data, and with statistical programs described in Bryce et al. (1980). Rankings of invertebrate abundance according to hostplants and vegetation types were performed as described in Zar (1974). The patterns that emerged were then related to environmental data such as plant phenology, moisture conditions (precipitation and soil water), plant production, and temperature.

5.3.3.3 Amphibians and Reptiles Reptiles were censused only in June 1982 following the procedure outlined in the Environmental Monitoring Manual. Amphibians were monitored by opportunistic sightings.

5.3.3.4 Birds For each bird sighted from transects, a perpendicular distance from the transect to the bird was estimated. For each species, perpendicular distances were converted to density estimates using program "TRANSECT" (Burnham et al. 1980). Density was converted to consuming biomass

by multiplying density for each species by its weight, raised to the 0.633 power. Differences were tested with Analysis of Variance (ANOVA) using the significance of $\alpha = 0.10$ to maximize the detection of change (WRSOC 1982).

April bird sampling was reduced to three days on four transects. June sampling remained at five days on eight transects (plus R-4).

Raptor nests were located by an aerial survey and extensive ground surveys in February and April 1982. Use of each nest was checked in April and June. During these surveys every suitable cliff on and within 2 km of tracts Ua and Ub was searched.

A bald eagle survey was conducted by helicopter on February 12, 1982. Lcoations of all bald eagles were mapped.

Abundances of migratory waterfowl along the White River was sampled by three canoe transects on the White River in April 1982. The numbers and species of waterfowl were recorded and their locations were mapped to the nearest 0.1 mile.

5.3.3.5 Mammals Density of cottontails along each transect was calculated according to the computer program "TRANSECT," details of which are found in Burnham et al. (1980). All mule deer sightings within 3 km (rather than 1.6 km as stated in the Environmental Monitoring Manual) of tracts Ua and Ub were recorded and mapped during 1982.

5.4 PROGRAM RESULTS AND ANALYSIS

5.4.1 Soil Invertebrates

5.4.1.1 Nematodes Nematode total density, species richness, and species diversity all varied significantly over sample periods (one-way ANOVA, $p<0.001$ for all) and transects (one-way ANOVA, $p<0.01$ for all). Density of nematodes (Fig. 5.4-1) was greatest from October 1981 to April 1982 during months of high soil moisture (Fig. 5.4-2, p 0.05). Density increased again in October 1982. Species richness (Fig. 5.4-3) and species diversity showed a similar pattern; high in October and December 1981, low in June and August 1982, and high again in October 1982. Species diversity and evenness changes little between sampling periods.

Samples were taken in April, June, August and October in both 1981 and 1982. Nematode density was significantly greater in April 1982 than April 1981, but density in June and August for both years did not differ significantly (Fig. 5.4-1). Surprisingly, nematode density in October was higher in 1982 than in 1981 despite the approximately equal soil moisture. Species richness and diversity was generally lower in 1982 for all months. These differences between years appear to be due to the dry spring and early summer in 1982.

Nematode density was high in Greasewood, especially G-1 and G-3, and Riparian (Fig. 5.4-1). Species richness (Fig. 5.4-3) and species diversity showed no consistent trends between transects. The Juniper transects, which have poor soils, had the lowest nematode density. In general, moist sites with well-developed soils had richer and more diverse nematode communities.

Nematodes can be divided into 3 trophic groups: herbivores or plant parasites (10 species), carnivores (1 species), and bacteriovores (7 species).

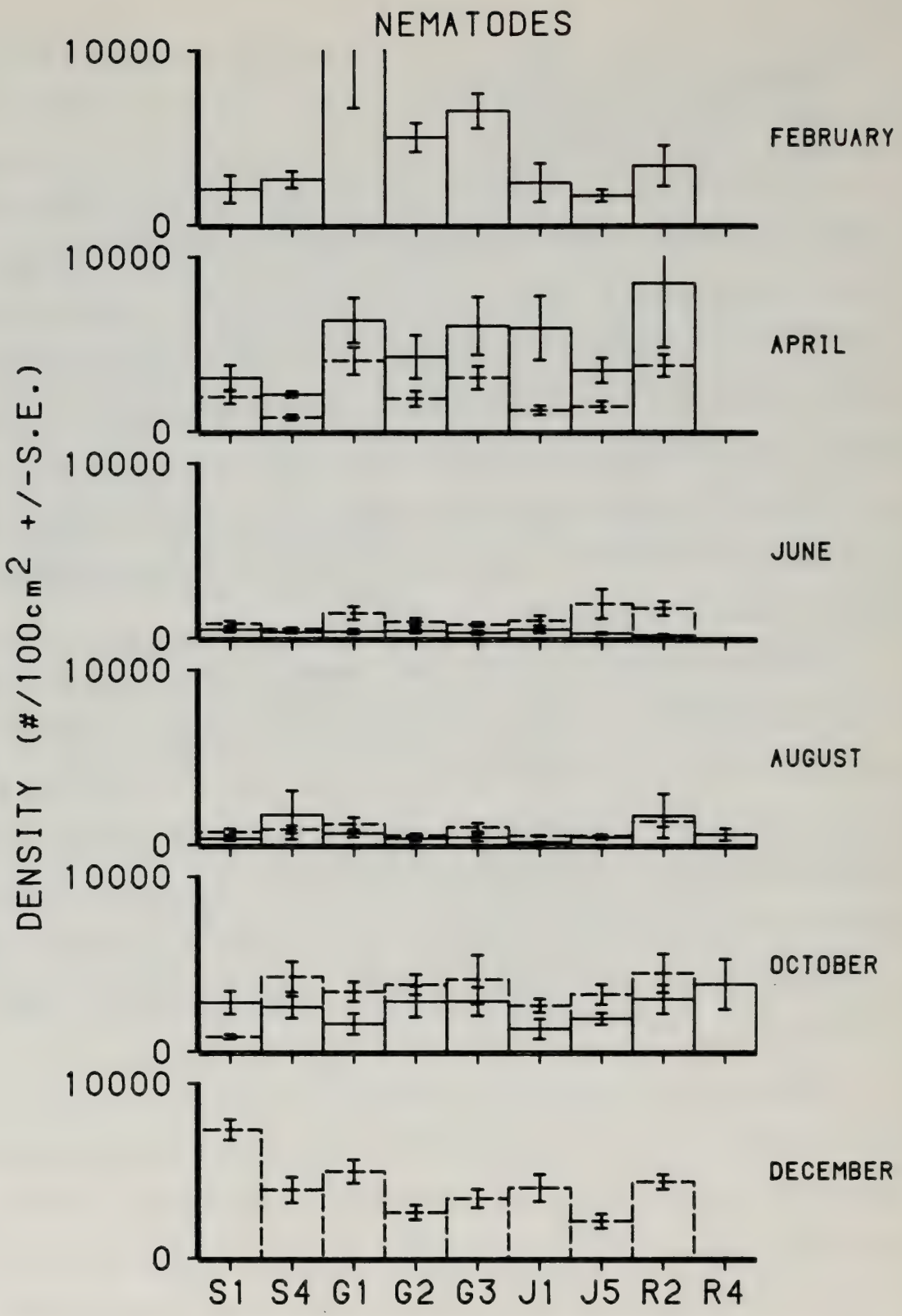


Fig. 5.4-1. Density (ind/100 cm^2±SE) of nematodes along 9 transects bimonthly from April 1981 to August 1982. Data from 1981 are shown with broken lines, those from 1982, in solid lines.

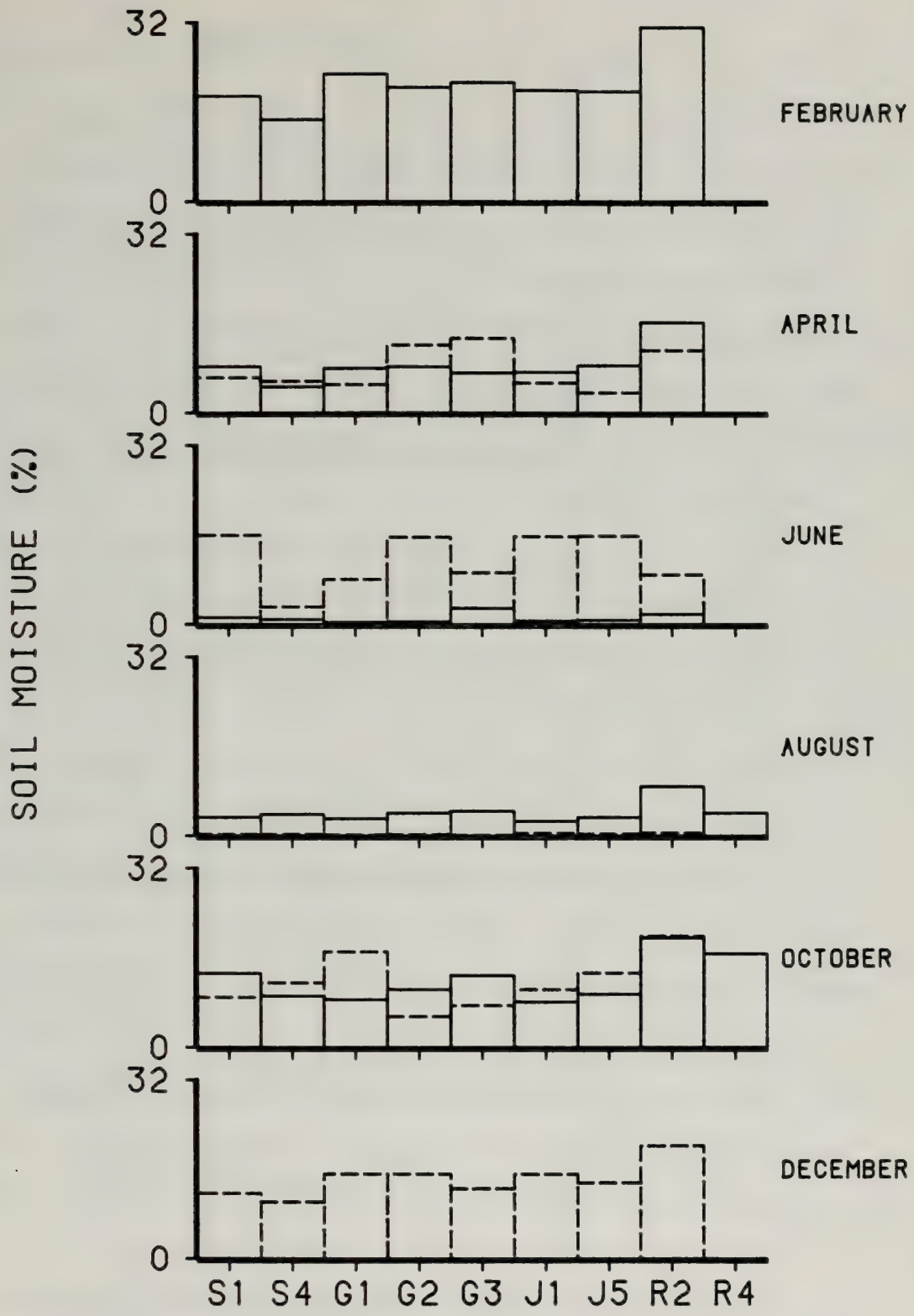


Fig. 5.4-2. Soil moisture (%) along 9 transects bimonthly from April 1981 to August 1982. Data from 1981 are shown with broken lines; those from 1982, in solid lines.

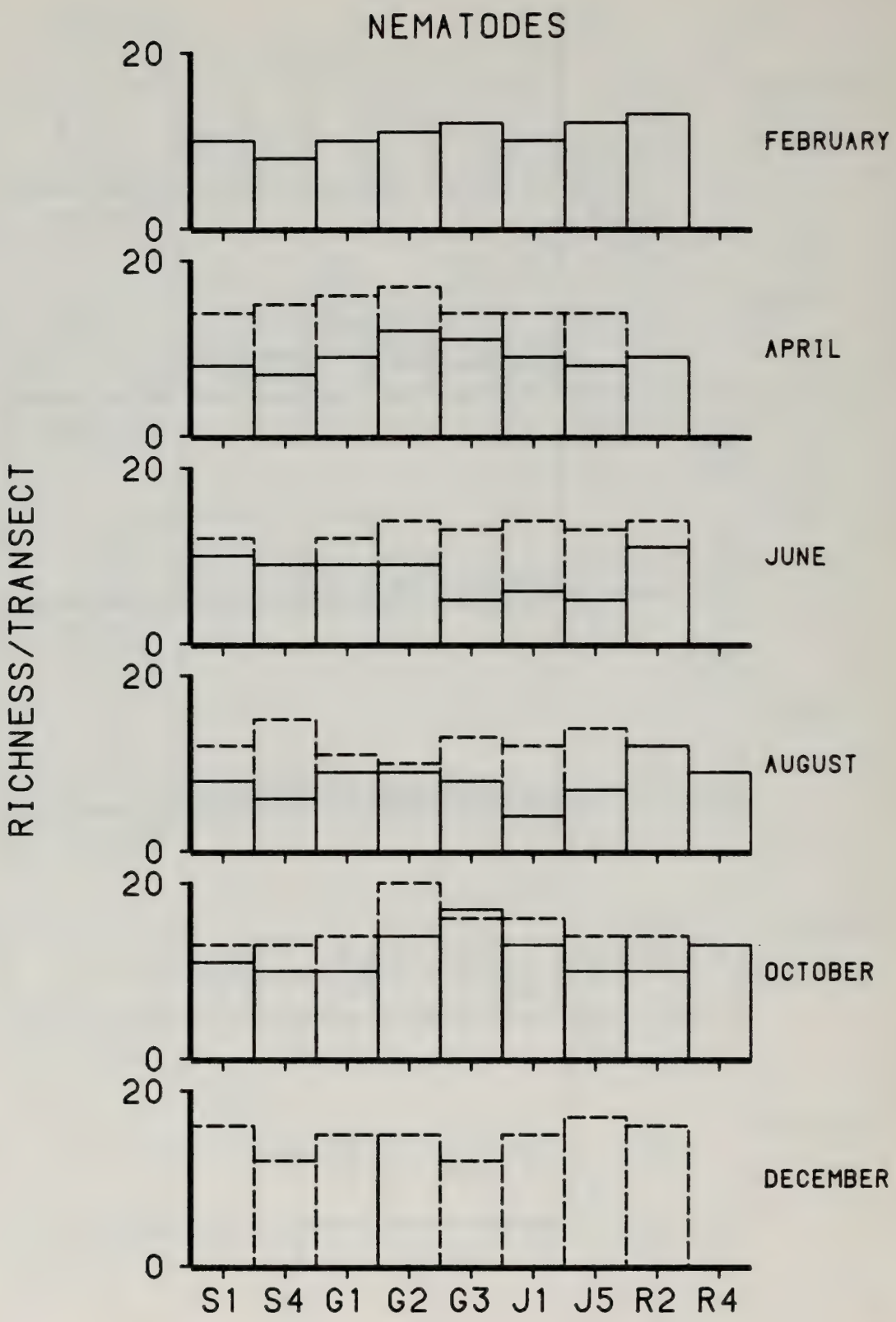


Fig. 5.4-3. Richness (taxa/transect) of nematodes along 9 transects bimonthly from April 1981 to August 1982. Data from 1981 are shown with broken lines; those from 1982, in solid lines.

Both herbivorous and bacteriovorous nematodes had high population densities in April, October, and December 1981 and February and April 1982 (Table 5.4-1, top, $p<0.05$, October 1982 was not included in this analysis). The much rarer carnivorous nematodes had highest populations in October and December 1981. Transects G-1, G-3, and R-2 had significantly higher populations of herbivorous and bacterivorous nematodes, whereas R-2 had the highest populations of carnivorous nematodes (Table 5.4-2, top, $p<0.05$). Again, these temporal and spatial patterns indicate that nematode communities are most well-developed on moist sites with deep soils. Because R-4 was only sampled in August and October 1982 it was not included in this analysis.

5.4.1.2 Microarthropods Total density, richness, and diversity of soil microarthropods varied significantly over sample periods (one-way ANOVA, $p<0.001$ for all) and species richness and diversity both varied significantly over transects (one-way ANOVA, $p<0.01$). Total density of microarthropods was not significantly different among transects ($P=0.14$).

Microarthropods were most abundant in April, October, and December 1981 and October and February 1982 (Fig. 5.4-4, $p<0.05$). Species richness (Fig. 5.4-5) and species diversity were also high during the same months. Evenness varied little among months. April 1981 had significantly higher density, richness and diversity than April 1982. These same measures were only slightly lower in June 1982 than in June 1981, with only diversity showing a significant change. Both richness and diversity were significantly higher in August 1982, compared to August 1981.

There were few major differences among transects. Microarthropod density was similar on all transects except R-2 and R-4, where it was greater in some months. Diversity had a pattern similar to that of richness; high on S-1, J-

Table 5.4-1. Months in which abundances (ind/sample) of soil invertebrates belonging to four trophic groups were significantly higher ($p<0.05$) than one or more months. October 1982 is not included; abundance was at least as high as in October 1981 (Fig. 5.4-1, 5.4-4).

	1981					1982			
	Apr.	June	Aug.	Oct.	Dec.	Feb.	Apr.	June	Aug.
Nematodes									
Herbivores	X			X	X	X	X		
Carnivores				X	X				
Bacteriovores	X			X	X	X	X		
Arthropods									
Herbivores	X								X
Carnivores	X			X	X				X
Detritivores	X			X	X	X			

Table 5.4-2. Transects from which abundances (ind/samples) of soil invertebrates belonging to four trophic groups were significantly higher ($p<0.05$) than one or more other transects. R-4 is not included because of only being sampled twice (August and October 1982).

	G-1	G-2	G-3	J-1	J-5	S-1	S-4	R-2
Nematodes								
Herbivores	X		X					X
Carnivores								X
Bacteriovores	X		X					X
Arthropods								
Herbivores								
Carnivores								X
Detritivores								

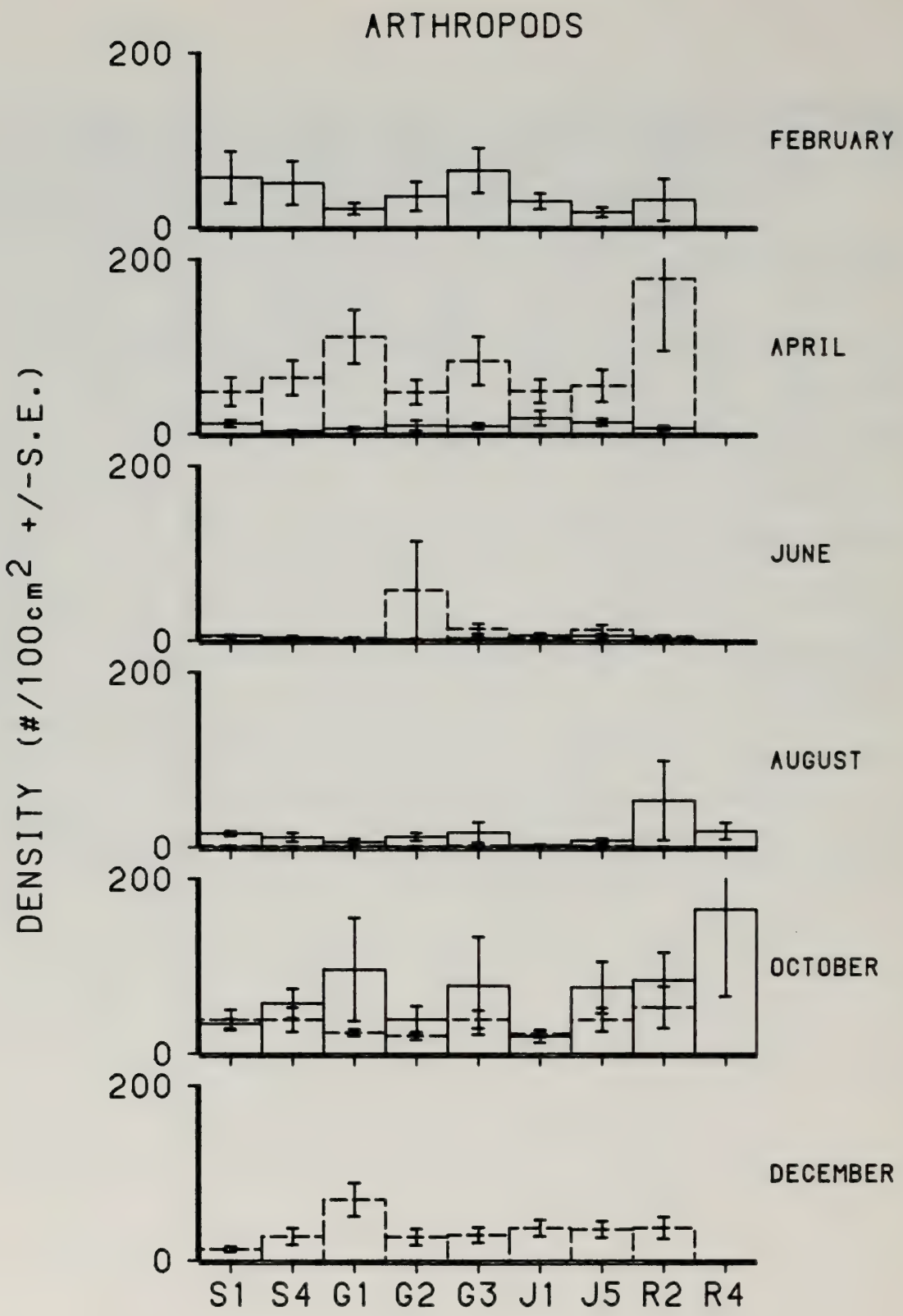


Fig. 5.4-4. Density (ind/100 cm^2±SE) of soil microarthropods along 9 transects bimonthly from April 1981 to August 1982. Data from 1981 are shown with broken lines; those from 1982, in solid lines.

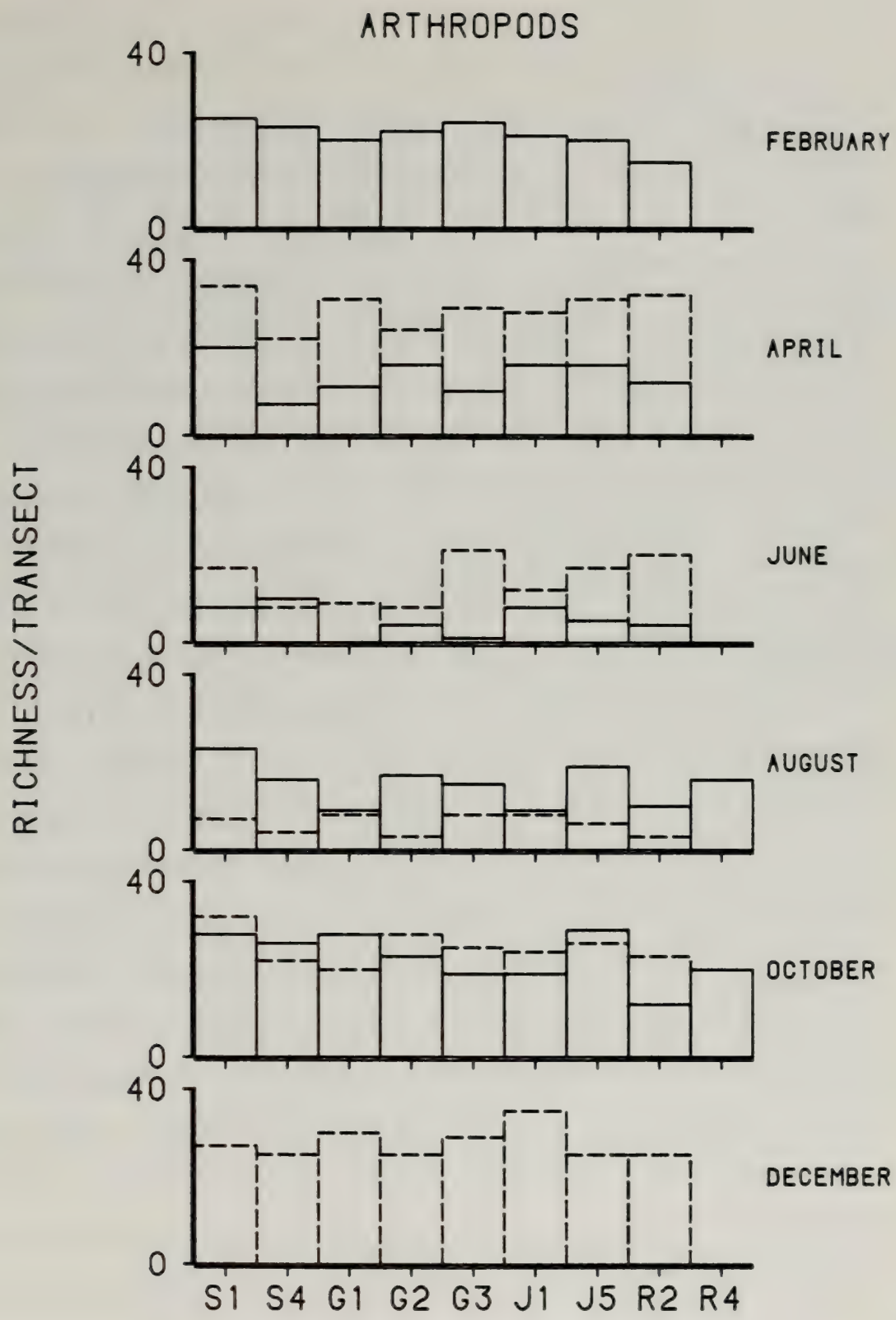


Fig. 5.4-5. Richness (taxa/transect) of soil microarthropods along 9 transects bimonthly from April 1981 to August 1982. Data from 1981 are shown with broken lines; those from 1982, in solid lines.

5, and very low on R-2.

Microarthropods can be divided into 3 trophic groups: herbivores (1 species), carnivores (13 species), and detritivores (detritus is dead plant material)(16 species). All trophic groups changed significantly in the high density usually occurring in April, October, and December 1981 and February and August 1982 (Table 5.4-1, bottom). These temporal patterns of population densities are similar to those of nematodes. There were no differences in density between transect except that carnivores were significantly more abundant on R-2 than all other transects ($p<0.05$)(Table 5.4-2, bottom). Richness and species diversity of trophic groups did not vary between transects.

5.4.1.3 Factors Influencing Soil Invertebrates Soil moisture, in concert with the characteristics and depth of the soil itself, is probably the most important determinant of soil invertebrate community structure. Nematodes, especially, are highly dependent on soil moisture. Fig. 5.4-2 illustrates that soil moisture was highest during the fall, winter, and early spring; ranging from 10 to 25%. The summer months were not only much drier but soil moisture was more variable among sites. Despite the winter cold with its concommitant freezing and thawing of the soil, a seemingly severe conditon for soil invertebrates, nematodes and microarthropods were abundant in the moist winter months. Greasewood and Riparian, habitats with deep soils that retain moisture longer than the soils in Juniper and Shadscale, also had the most well-developed soil invertebrate, especially nematode, comunities.

In August 1982 a flash flood that deposited 5 to 30 cm of soil on the R-2 transect affected the soil invertebrate community. The next sampling period (October 1982), showed reduced values of arthropod richness, diversity and evenness, indicating that some species, perhaps sensitive ones, were decimated

while others became more numerous. This differential species response shows that changes in the structure of the arthropod community may reflect different types of impacts. Nematodes, on the other hand, apparently responded to this flooding and soil deposition by a decline in density only. Thus, nematodes responded as a group to the disturbance.

5.4.2 Foliage Invertebrates Foliage invertebrates are critical components of the structure and function of arid ecosystems. They significantly affect ecosystems through their roles as plant tissue consumers, seed consumers, soil organisms during part of their life cycles, and as important prey for their vertebrate predators. In addition, due to their short generation time and sensitivity to environmental change, they react quickly to fluctuations in water and temperature. These characteristics of the foliage invertebrate fauna make it valuable in the environmental monitoring program for two reasons. First, foliage invertebrates provide a critical link between climate, soils, plants, and vertebrates. Changes in environmental factors, either natural (e.g., climatic) or man-made (e.g., mining), will result in changes in foliage invertebrate faunas, which in turn, may result in changes in the birds, mammals, and reptiles which feed upon them. Second, since invertebrates are abundance and closely linked in space and time to their environment, they are ideally suited to tracking environmental change. Foliage invertebrates will provide an index of "permanency and diversity" of the ecosystem before, during, and after potential disturbances (Green and Knight 1980).

Few studies have dealt with relationships between mining and foliage invertebrates (Hawkins and Cross 1982). Invertebrates have been studied in relation to other man-made environmental perturbations, including construction

of transmission lines (Butt et al. 1982, Ditsworth et al. 1982, Johnson et al. 1981), grazing (Morris 1967, Bellows et al. 1982), burning (Bulan and Barrett 1971, Nagel 1973), mowing (Bulan and Barrett 1971, Jensen et al. 1973), radioactivity (Crossley and Howden 1961), cultivation (Allan et al. 1975), and air pollution (Hughes et al. 1981, 1982). These studies have together shown that invertebrates are significantly affected by temperature, precipitation, soil water, plant water, and plant production, and that they react quickly to changes in these variables.

Invertebrates may be important during the revegetation of the spent oil shale by feeding on or pollinating the plants. This baseline study -- by offering quantitative data on composition and variation in foliage invertebrates across years, habitats, plant species, and plant individuals -- will allow assessment of normal levels of foliage invertebrates on newly revegetated areas. Foliage invertebrates will need to be assessed and dealt with accordingly to prevent undesirable plant damage. Paradoxically, irrigation of the revegetaed areas may create more favorable conditions for growth of insect populations such as grasshoppers, as has happened in other arid regions (Rivnay 1964). Herbivory, especially by insects, along with drought stress (compounded by competition), have been cited as the major causes of mortality in seedlings of desert plants (Parker 1982, Cook 1979). These two factors will be important to consider in relation to plant establishment during the revegetation process on Tracts Ua and Ub. Finally, the particular planting patterns used on the revegetated areas will be an important determinant of initial and later foliage invertebrate faunas, as has been found by others (Ostlie 1979, Spangler and Norton 1982).

5.4.2.1 Climate and Plant Production Trends June degree-days (summation of the total degrees that the mean daily temperatures exceeded 15°C for each day of the month) in 1982 was lower than in 1981 (Fig. 5.4-6). The difference in water conditions between the 2 years is indicated by differences in percent soil moisture (Fig. 5.4-6): soil moisture was higher in 1982 in both April and August. Thus 1982 was a colder, wetter year.

Annual-plant biomass was greater in 1982, compared to 1981 (Table 5.4-3). Mean annual-plant biomass was greatest in Riparian followed by Greasewood, Shadscale and Juniper.

5.4.2.2 Entire Site (All Hostplants and Vegetation Types) A summary of hostplants, vegetation types, and transects sampled, along with the number of replicates is given in Table 5.4-4. During 1981 and 1982 we sampled a total of 3200 plants. The total number of foliage invertebrates captured and identified was 99218 individuals, comprising 139 families and 17 orders. The complete list of foliage invertebrate taxa collected and identified is available from Bio-Resources, Inc. or WRSOC. Herbivores (sap-feeders and leaf-chewers) were the most abundant functional group captured, comprising over 75% of all individuals (Table 5.4-5). Sap-feeders (e.g., aphids, leafhoppers, jumping plant lice, thrips, mirids) had the greatest abundance of all functional groups, followed by leaf-chewers, predators, parasites, decomposers, and others (Fig. 5.4-7). Leaf-chewers (e.g., caterpillars, grasshoppers, many beetles) had the greatest biomass, slightly greater than that of sap-feeders, followed by predators, and others (Fig. 5.4-8).

In comparing 1982 to 1981, two general patterns were apparent. First, foliage invertebrate abundance (ind/m^3) was much greater in 1982 than in 1981, for all hostplants combined (Fig. 5.4-6) and all hostplants considered indi-

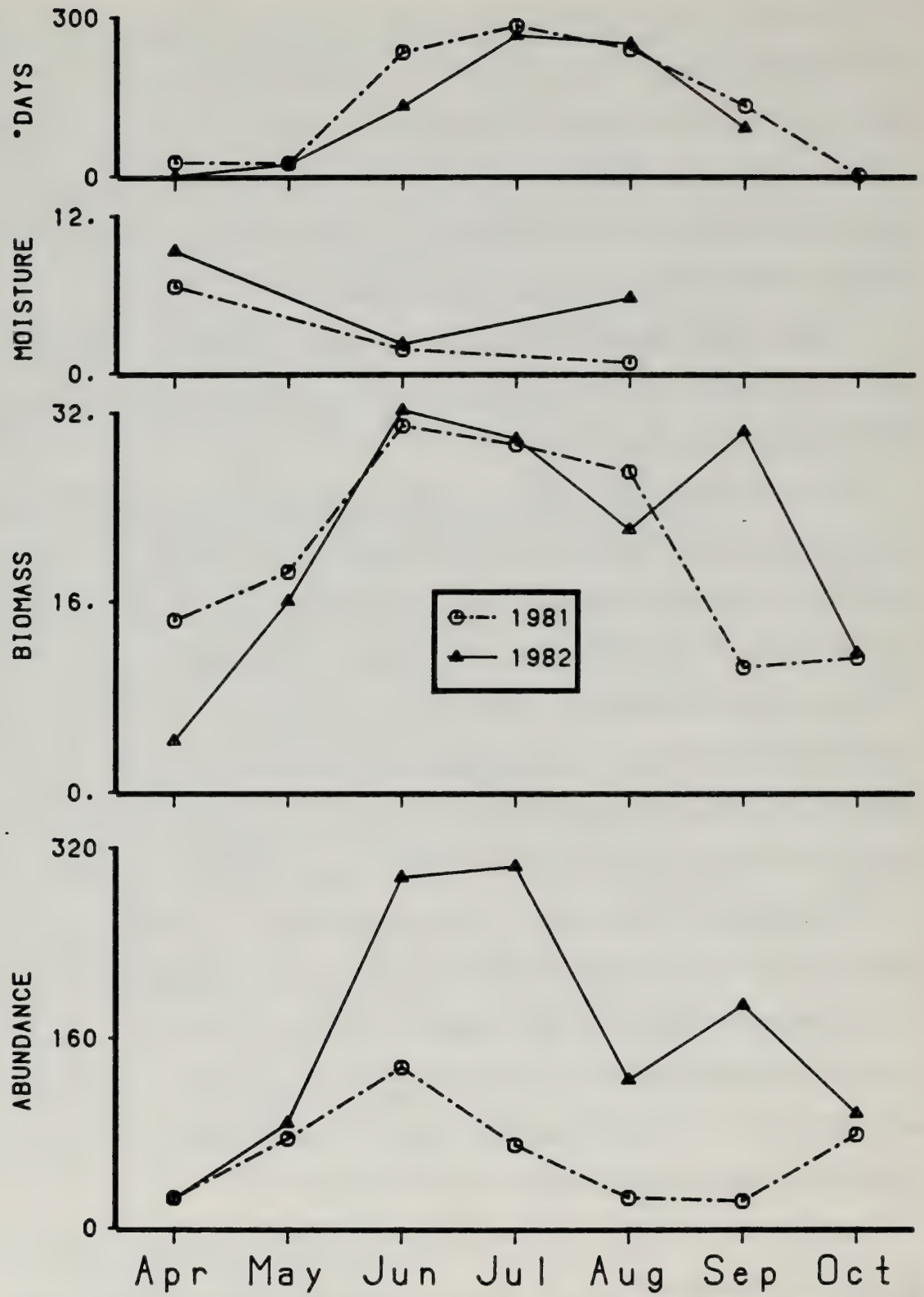


Fig. 5.4-6. Monthly abundance (ind/m^3) and biomass (mg/m^3) of foliage invertebrates, soil moisture (%), and degree-days (number of days multiplied by mean daily temperature > 15°C). Data are from sweep samples.

Table 5.4-3. Mean abundance (ind/m³) and biomass (mg/m³) of foliage invertebrates, and annual plant biomass (g/m³), in 4 vegetation types, 1981 and 1982.

		Foliage-Invertebrates		Annual-Plant
Sites	Years	Abundance	Biomass	Biomass
Greasewood	1981	66.1	23.7	15.6
	1982	158.1	23.2	21.6
Juniper	1981	64.9	25.0	0.4
	1982	137.5	24.7	0.4
Shadscale	1981	38.4	12.7	9.2
	1982	56.8	13.7	24.8
Riparian	1981	108.4	26.3	51.6
	1982	324.8	22.2	68.0

Table 5.4-4. Vegetation types and hostplants sampled during 1981 and 1982. Sampling occurred from April to October unless otherwise specified. Values represent number of replicates taken each month sampled.

Vegetation Type	Transect	Hostplant	1981	1982	
			Sweep	Sweep	Beat
Greasewood	G-1	Big Sagebrush	20[1]	10	10
		Rubber Rabbitbrush	10	10	-
		Greasewood	10	10	-
	G-2	Big Sagebrush	20[1]	10	10
		Spiny Hopsage	-	10	-
	G-3	Big Sagebrush	20[1]	10	10
Juniper	J-1	Big Sagebrush	20[1]	10	10
		Utah Juniper	10	-	10
		Sticky-leaved Rabbitbrush	10	10	-
	J-5	Big Sagebrush	20[1]	10	-
Shadscale	S-1	Big Sagebrush	20[1]	10	10
		Shadscale	10	10	-
		Spiny Horsebrush	10[2]	10	-
		Sticky-leaved Rabbitbrush	10[3]	-	-
	S-4	Big Sagebrush	20[1]	10	10
Riparian	R-2	Big Sagebrush	20[1]	10	10
		Rubber Rabbitbrush	10	10	-
		Cottonwood[4]	-	-	10
	R-4	Big Sagebrush	-	-	10
Bunchgrasses	BG-1	*Agropyron spicatum*[5]	-	-	10
		Oryzopsis hymenoides[5]	-	-	10

[1] reduced to 10 samples in August through October
[2] not sampled in April
[3] sampled in April only
[4] five trees sampled in R-2, 5 in R-4, in June only
[5] both grasses treated as one taxon

Table 5.4-5. Total numbers of individuals caught in 1981 and 1982 in 9 functional groups of foliage invertebrates. Data are from sweep and beat samples. Number of samples were not equal (see Table 5.4-4).

	1981	1982	
Functional Group	Sweeping	Sweeping	Beating
Sap-feeders	12,280	16,927	45,976
Leaf-chewers	1,183	1,056	3,772
Predators	1,113	1,130	3,307
Parasites	740	930	1,592
Decomposers	381	511	3,948
Omnivores	340	487	774
Flower-feeders	123	77	152
Diptera	780	717	665
Non-feeders	63	51	143
TOTAL	17,003	21,886	60,329

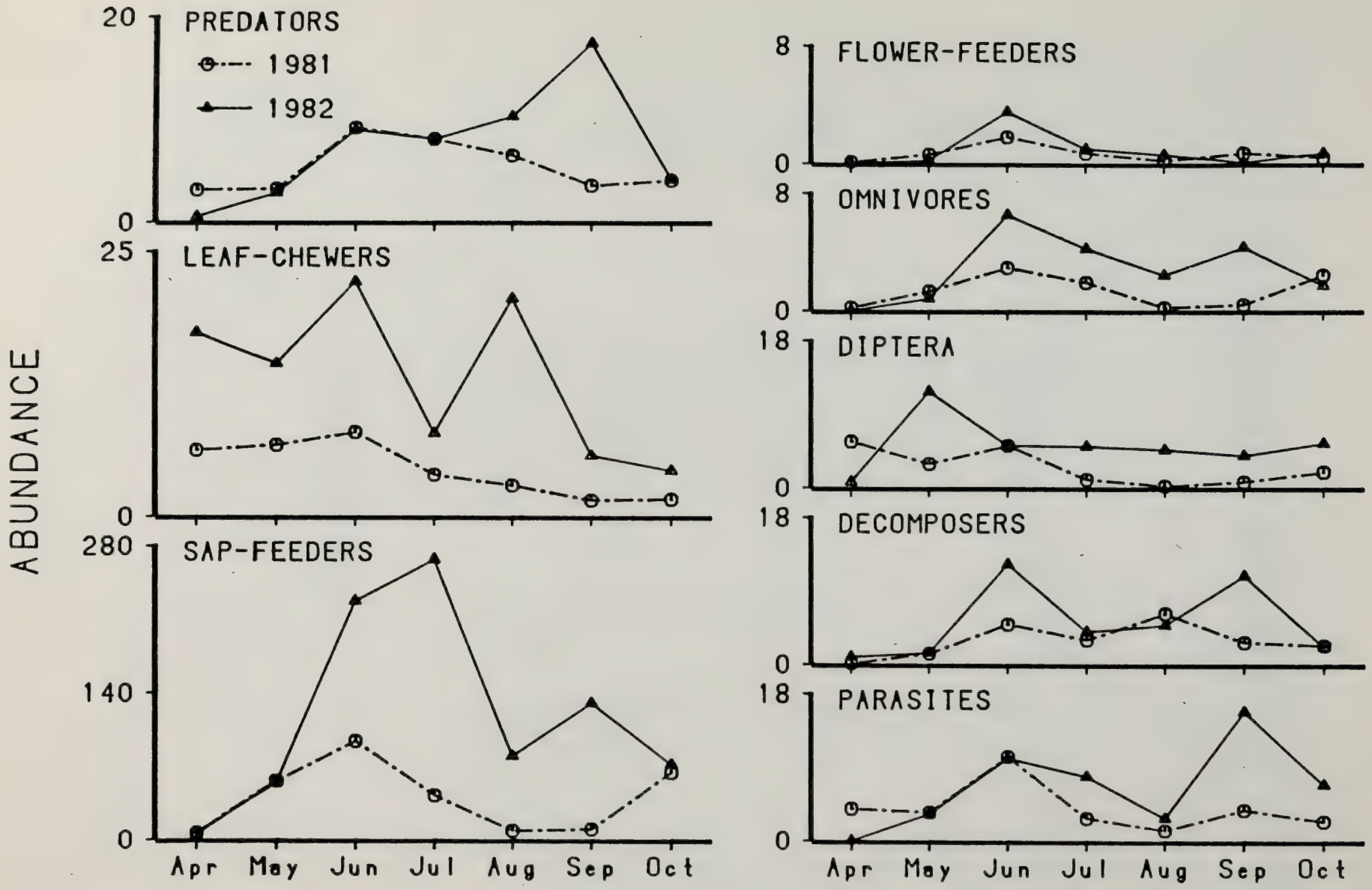


Fig. 5.4-7. Mean abundance (ind/m^3) of foliage invertebrates in 8 functional groups from sweep samples taken monthly from April to October, 1981 and 1982.

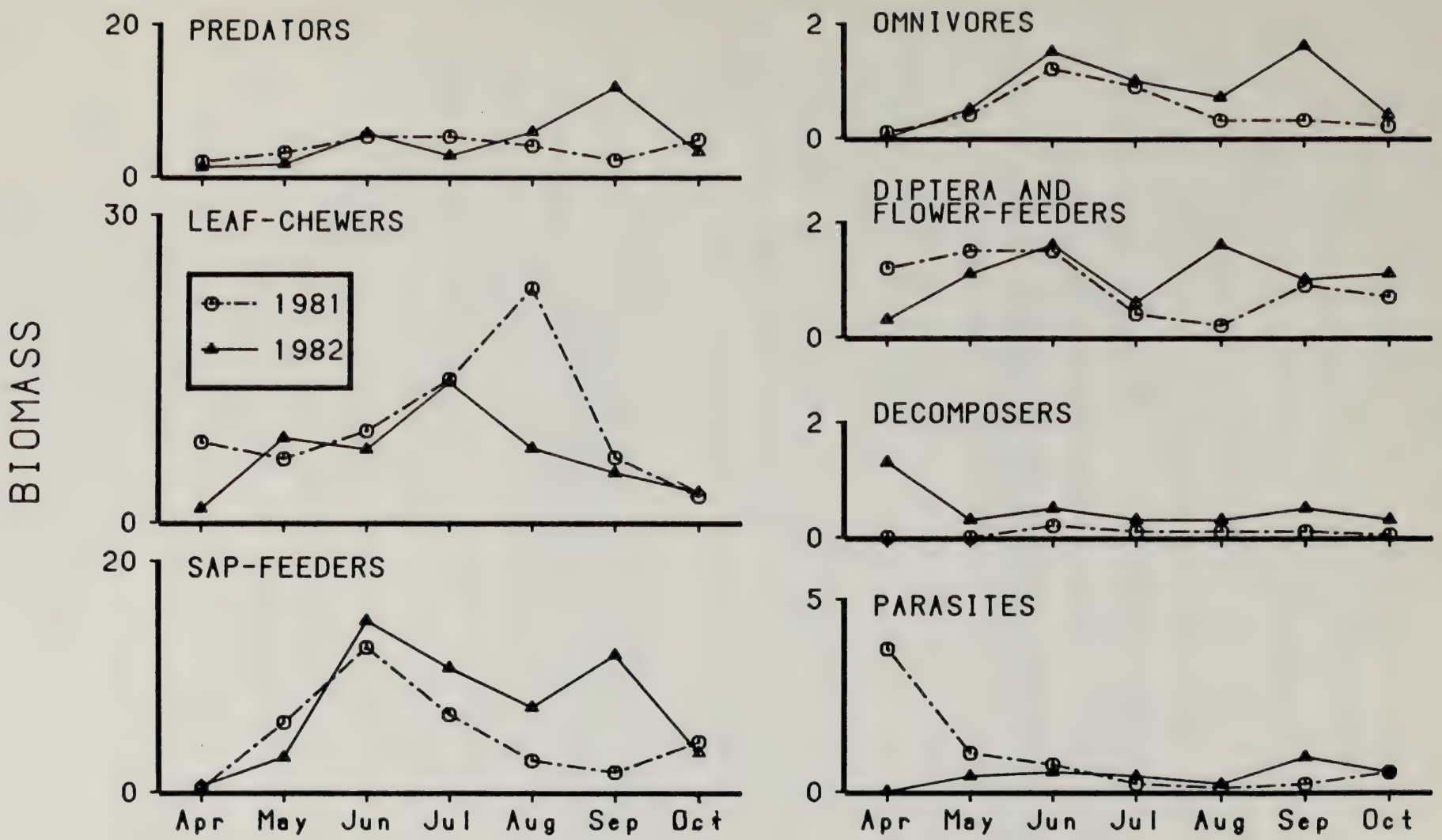


Fig. 5.4-8. Mean biomass (mg/m^3) of foliage invertebrates in 7 functional groups from sweep samples taken monthly from April to October, 1981 and 1982.

vidually (Figs. 5.4-9 through 5.4-11). For all hostplants combined the difference in abundance between years was significant ($p<0.001$), as was the difference among months ($p<0.001$, ANOVA). The second general pattern was that populations peaked later in the season in 1982, and showed continued higher levels after July. This pattern was statistically significant as the year X month interaction revealed ($p<0.001$), for all hostplants combined. The higher levels and delayed peaks of foliage invertebrates in 1982 were evident for most functional groups (Fig. 5.4-7). Greater foliage invertebrate abundance in 1982 was probably the result of higher moisture availability whereas delayed population peaks in 1982 was probably the result of a later increase of degree-days (Fig. 5.4-6). These patterns and others will be discussed by focusing on differences among hostplants and vegetation types. Biomass (mg/m^3) of foliage invertebrates was approximately equal between 1981 and 1982 for all hostplants combined, but population development was slightly later in the summer (Fig. 5.4-8).

5.4.2.3 Hostplant Species Of the hostplants sampled with the same technique in 1981 and 1982 (sweep net), all showed greater foliage invertebrate abundance (ind/m^3) in most months of 1982 (Figs. 5.4-9 through 5.4-11, Table 5.4-6). The greatest increase was for big sagebrush (*Artemisia tridentata*), which had a mean abundance 3.3 times greater in 1982 ($p<0.001$). There were also increases of 2.2 for greasewood (*Sarcobatus vermiculatus*) ($p<0.001$), 2.0 for spiny horsebrush (*Tetradymia spinosa*) ($p<0.001$), 1.9 for rubber rabbitbrush (*Chrysothamnus nauseosus*) ($p<0.05$), 1.9 for sticky-leaved rabbitbrush (*Chrysothamnus vicidiflorus*) (not significant), and 1.5 for shadscale (*Atriplex confertifolia*) (not significant). Mean richness (number of families) was greater in 1982 on big sagebrush, both rabbitbrushes, grease-

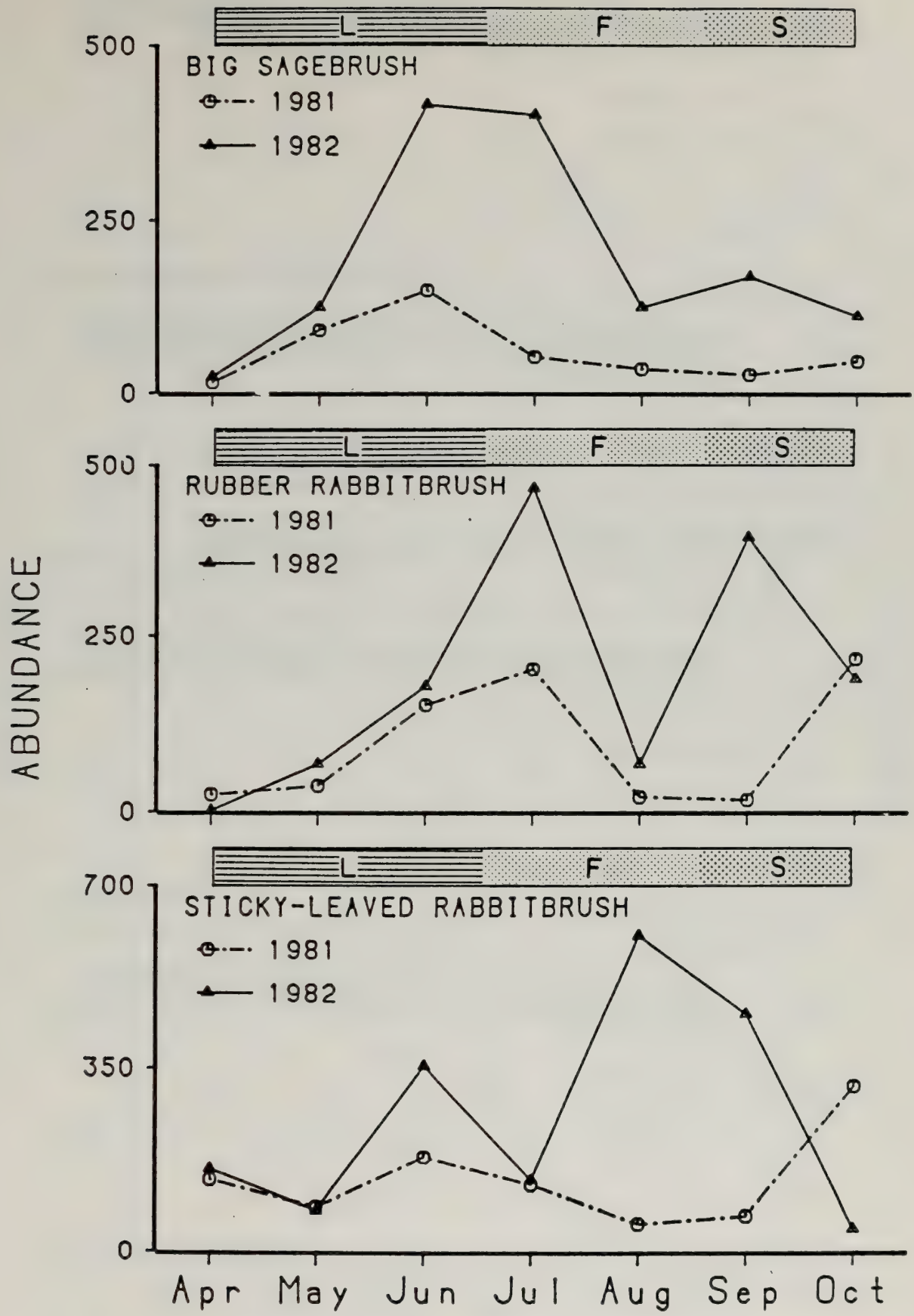


Fig. 5.4-9. Monthly abundance (ind/m^3) of foliage invertebrates in 1981 and 1982 on big sagebrush, rubber rabbitbrush, and sticky-leaved rabbitbrush. Gross plant phenology for 1982 is shown in the horizontal bar above each graph. Phenological stages were leaf (L), flowering (F), and seed (S).

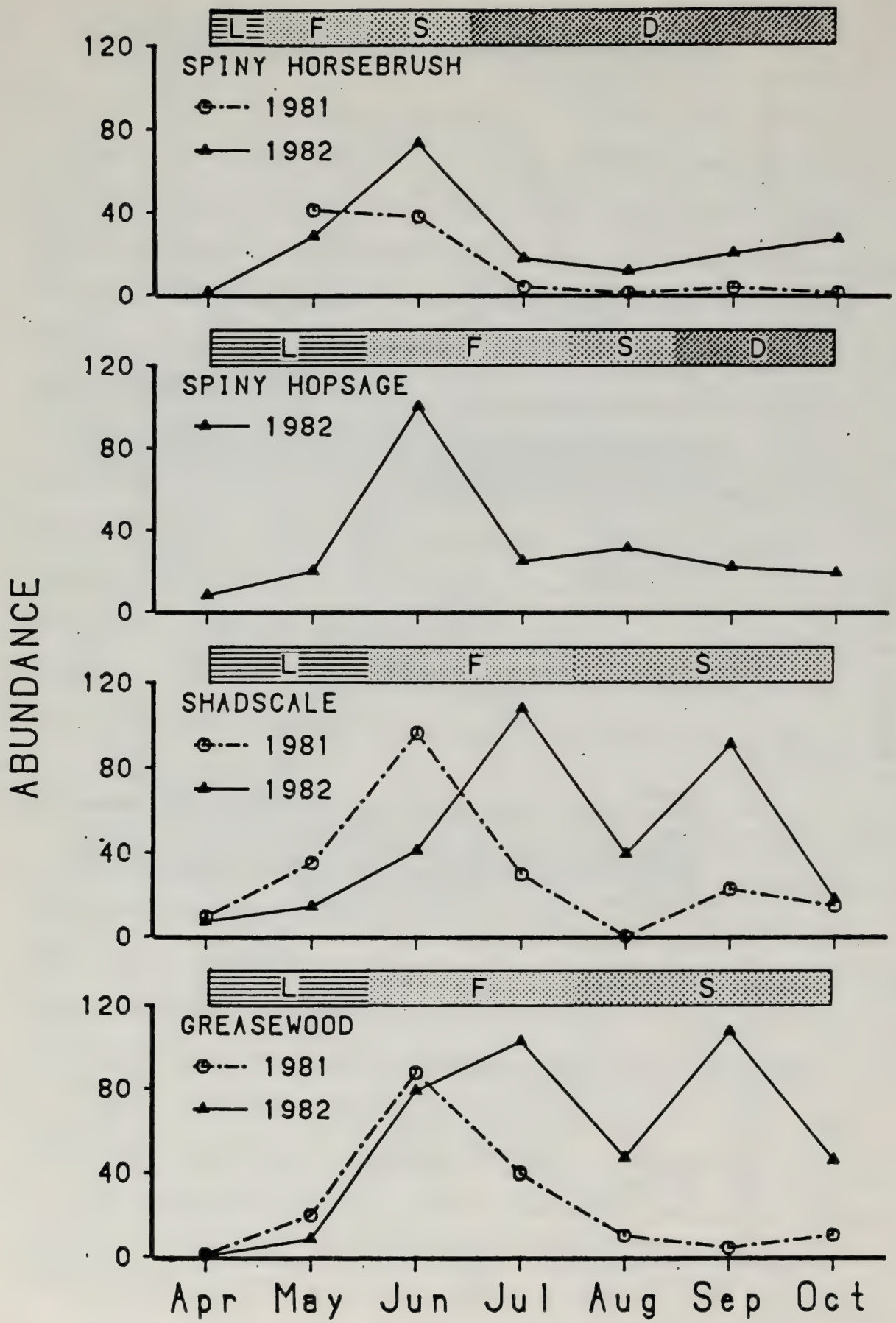


Fig. 5.4-10. Monthly abundance (ind/m^3) of foliage invertebrates in 1981 and 1982 on spiny horsebrush, spiny hopsage, shadscale and greasewood. Gross plant phenology for 1982 is shown in the horizontal bar above each graph. Phenological stages were leaf (L), flowering (F), seed (S), and leaf drop (D).

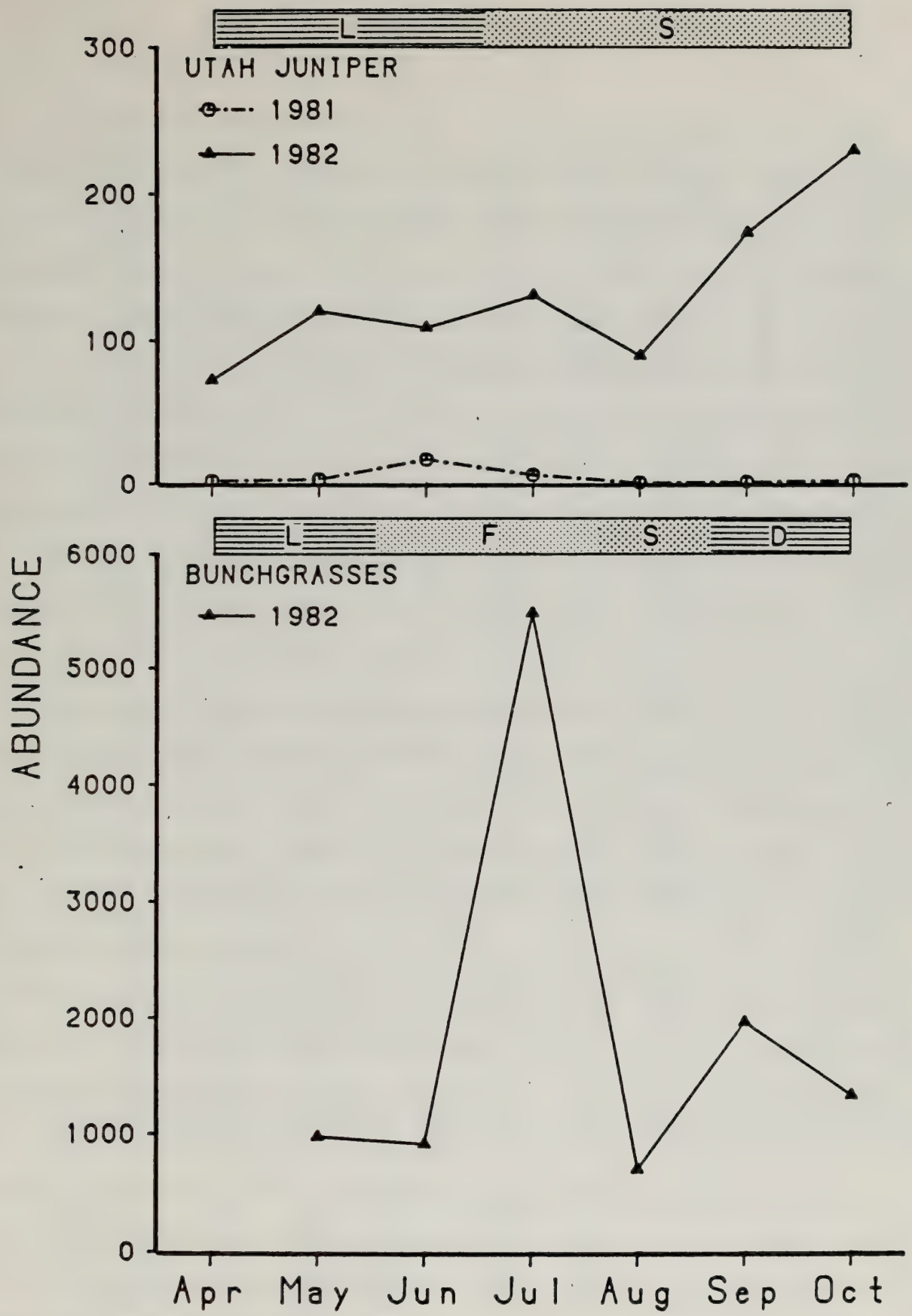


Fig. 5.4-11. Monthly abundance (ind/m^3) of foliage invertebrates in 1981 and 1982 on Utah juniper, and bunchgrasses (Agropyron spicatum and Oryzopsis hymenoides). Gross plant phenology for 1982 is shown in the horizontal bar above each graph. Phenological stages were leaf (L), flowering (F), and seed (S).

Table 5.4-6. Mean abundance (ind/m³) ± standard deviation of foliage invertebrates on various hostplants from April to October in 1981 and 1982. S corresponds to sweep samples, B corresponds to beat samples. Bunchgrasses were Agropyron spicatum and Oryzopsis hymenoides.

	yr	April	May	June	July	August	September	October
Big Sagebrush	81S	15±15	92±170	150±141	52±76	35±48	21±46	46±96
	82S	24 70	125 188	414 1153	399 2113	125 461	169 187	112 166
	82B	143 193	951 1015	1516 2469	1599 4064	496 1249	883 991	1864 1910
Rubber Rabbitbrush	81S	24 18	36 35	149 176	201 251	20 22	16 20	216 236
	82S	1.7 2.5	67 130	176 393	466 1071	67 64	394 645	186 140
Sticky-leaved Rabbitbrush	81S	136 487	85 59	179 235	126 207	54 93	69 120	315 698
	82S	156 322	78 101	354 245	135 58	606 675	454 566	45 45
Greasewood	81S	0.9 1.6	20 12	87 66	39 24	10 7.2	4.4 4.4	10 9.8
	82S	0.3 0.9	8.4 8.7	79 40	102 78	46 33	107 44	45 45
Utah Juniper	81S	2.2 2.5	3.3 1.6	17 23	6.4 4.6	0.8 1.5	1.2 1.4	2.3 1.3
	82B	72 209	120 176	109 108	131 80	89 120	174 167	230 193
Shadscale	81S	9.5 15	34 180	96 180	29 42	0.0 0.0	22 40	14 34
	82S	7.1 15	14 26	40 43	107 121	39 33	90 91	17 20
Horsebrush	81S	-	40 35	37 42	3.8 8.4	1.0 2.1	3.6 6.7	1.1 2.3
	82S	1.2 3.1	28 44	73 54	17 8.8	11 13	20 18	27 41
Hopsage	82S	7.8 16	19 15	89 103	24 20	31 41	22 26	19 20
Bunchgrasses	82B	-	978 1642	918 997	5481 8554	699 1166	1963 2721	1332 1487
Cottonwood	82B	-	-	263 326	-	-	-	-

wood, shadscale, and spiny horsebrush. The largest difference was on big sagebrush, even though fewer samples were taken in 1982 (Table 5.4-7). Mean values of diversity (H') were greater in 1982 for sticky-leaved rabbitbrush, greasewood, spiny horsebrush, and shadscale, but lower in 1982 for big sagebrush and rubber rabbitbrush (Table 5.4-7).

In both 1981 and 1982 foliage invertebrate abundance was significantly different between months for all hostplants considered individually ($p<0.001$). Foliage invertebrate abundance typicaly peaked in June and July, with secondary peaks in September and October (Figs. 5.4-9 to 5.4-11). Family-level richness and diversity followed the same pattern, being low in the spring and peaking in early to mid-summer (Table 5.4-7). Figures 5.4-9 through 5.4-11 demonstrate that these monthly population changes were related to gross plant phenology of the individual hostplant, which in turn is correlated with percent soil moisture. Foliage invertebrate abundance peaked on big sagebrush in the leaf and flowering stages and on Utah juniper (*Juniperus osteosperma*) in the "seed" stage. For all other hostplant species it peaked in the flowering to seed production stages. The 2 hostplants which lost their leaves during the summer, spiny hopsage (*Grayia spinosa*) and horsebrush, had the lowest levels of foliage invertebrates after August (Fig. 5.4-10). Thus the other hostplants which retained their leaves and had the ability for continued plant biomass production also sustained greater levels of foliage invertebrates.

We observed significant differences among hostplants in foliage invertebrate abundance ($p< 0.001$). Mean invertebrate abundance during 1981 and 1982 was greatest on sticky-leaved rabbitbrush and lowest on Utah juniper. Analysis of abundance ranks showed that sticky-leaved rabbitbrush, rubber rabbitbrush, and big sagebrush had the greatest invertebrate abundance and were not

Table 5.4-7. Family-level richness (R) and Shannon-Wiener diversity (H') of foliage invertebrates on various hostplants from April to October in 1981 and 1982. Number of replicates was not equal (see Table 5.4-4). Diversity was calculated using abundance (ind/m³) of families. S corresponds to sweep samples, B corresponds to beat samples.

	yr.	April		May		June		July		August		September		October		Mean	
		R	H'	R	H'	R	H'	R	H'	R	H'	R	H'	R	H'	R	H'
Big Sagebrush	81S	40	2.84	58	2.14	61	2.49	60	2.57	35	2.39	35	0.66	25	2.12	45	2.17
	82S	19	2.15	43	2.41	70	1.78	57	1.04	54	2.11	62	2.25	48	2.01	50	1.96
	82B	30	2.34	52	2.44	73	1.72	78	1.66	65	2.45	73	2.31	72	2.17	63	2.16
Rubber Rabbitbrush	81S	27	1.96	34	2.79	42	2.12	40	1.79	33	1.50	17	1.77	31	1.05	32	1.99
	82S	5	1.43	28	2.38	41	2.20	47	1.42	41	2.18	41	1.67	35	1.82	34	1.87
Sticky-leaved Rabbitbrush	81S	11	1.75	19	2.57	22	2.08	11	1.68	8	1.51	12	1.45	14	0.74	13	1.67
	82S	1	0.00	19	2.47	18	2.28	17	2.40	17	1.65	24	2.03	7	1.55	15	1.77
Greasewood	81S	4	1.10	12	0.80	26	1.91	21	2.06	13	1.89	8	1.91	6	1.44	13	1.59
	82S	1	0.00	9	1.68	19	2.41	22	1.86	20	2.43	22	2.32	18	2.34	15	1.86
Utah Juniper	81S	8	1.47	12	1.66	18	2.19	13	2.26	4	0.86	5	1.47	8	1.96	10	1.70
	82B	8	1.32	20	2.30	25	2.28	33	2.68	41	2.77	19	1.64	27	1.96	25	1.14
Shadscale	81S	5	1.30	7	1.40	12	1.82	6	1.65	0	0.00	5	1.22	3	0.92	5	1.19
	82S	2	0.61	5	1.56	10	1.76	9	1.61	9	1.87	7	1.83	5	1.36	7	1.51
Spiny Horsebrush	81S	-	-	15	2.53	19	2.65	3	1.09	2	0.69	3	0.98	2	0.69	7	1.44
	82S	2	0.45	7	1.68	15	2.10	8	1.97	3	0.84	6	1.28	8	1.88	8	1.63
Spiny Hopsage	82S	2	0.51	8	1.92	15	1.54	9	1.84	10	1.72	12	1.95	7	1.61	9	1.58
Bunchgrasses	82B	-	-	17	2.32	15	2.74	13	0.86	15	2.06	24	2.78	23	2.49	18	2.04
Cottonwood	82B	-	-	-	-	24	1.97	-	-	-	-	-	-	-	-	24	1.97

statistically different from each other, followed by groups composed of greasewood and shadscale, spiny hopsage and horsebrush, and Utah juniper (Table 5.4-8). These groupings appear to be explainable on the basis of phenological growth patterns, observed in 1982 (Figs. 5.4-9 through 5.4-11). Both rabbitbrushes and big sagebrush show continual growth throughout the season. Greasewood and shadscale had rapid growth early in the season, retained their leaves, but showed little or no more growth after July. Spiny hopsage and horsebrush dropped most of their leaves in August.

Family-level richness (R) showed a pattern similar to that of abundance (Table 5.4-7). Big sagebrush and rubber rabbitbrush had the highest levels of R, followed by sticky-leaved rabbitbrush, greasewood, Utah juniper, spiny hopsage, spiny horsebrush, and shadscale. Patterns of family-level diversity were roughly the same, though less clear.

In 1982, sampling of bunchgrasses, Agropyron spicatum and Oryzopsis hymenoides, began. No comparison of abundance on bunchgrasses to shrubs is made because different life forms (grass vs. shrub) are not comparable using volume measurements. Family-level richness appears to be moderate for bunchgrasses (Table 5.4-7). Cottonwood (Populus fremontii) was sampled in June 1982. It had moderate levels of abundance and diversity (Tables 5.4-6 and 5.4-7). However, due to the large volume of cottonwood, this tree species is a very important producer of invertebrates in Riparian vegetation.

5.4.2.4 Vegetation Types The differences in foliage invertebrate faunas between vegetation types may be viewed by comparing them without regard to hostplant (i.e., by lumping all hostplant species), and also by comparing big sagebrush by itself in different vegetation types. In both cases the same patterns of yearly and monthly variations appeared as was observed for indi-

Table 5.4-8. Rankings of abundance (ind/m^3) of foliage invertebrates collected in sweep samples of 8 hostplants. Abundances are means across all years and months. Ranks were tested with Newman-Keuls multiple comparison test (Zar 1974) on log (X+1) transformation. Ranks that are not significantly different ($p<0.05$) are shown connected by lines.

Hostplant	Abundance
Sticky-leaved Rabbitbrush	195.5
Rubber Rabbitbrush	145.6
Big Sagebrush	119.5
Greasewood	38.3
Shadscale	37.5
Spiny Hopsage	32.1
Spiny Horsebrush	20.6
Utah Juniper	4.7

vidual hostplants. Significant differences in abundance (ind/m^3) among years and months ($p<0.001$) occurred as well as a significant year X month interaction ($p<0.001$), which means that the invertebrate populations peaked in different months in 1981 and 1982. In particular, late season peaks were more evident in 1982.

For all hostplants together, or big sagebrush by itself, there were significant differences in foliage invertebrate abundance among vegetation types ($p<0.001$), and ranking patterns were essentially identical for 1981 and 1982 combined. In both cases the Riparian vegetation type had significantly greater ($p<0.05$) foliage invertebrate abundance than all other vegetation types. Greasewood and Juniper vegetation types were not statistically different, and both had significantly greater ($p<0.05$) abundance than Shadscale vegetation type (Table 5.4-9, see also Tables 5.4-10 and 5.4-11). Foliage invertebrate abundance usually peaked in June in Greasewood, Juniper, and Shadscale vegetation type and July in Riparian (Fig. 5.4-12). There was a significant month X vegetation interaction ($p<0.001$), which means that foliage invertebrate populations peaked in different months in different vegetation types.

Foliage invertebrate richness showed patterns similar to abundance. Big sagebrush had highest levels of family-level richness in Riparian vegetation type, followed by Greasewood, Juniper, and Shadscale (Table 5.4-12). Richness peaked in June in Greasewood, Juniper, and Shadscale vegetation types, and it peaked in June to July in Riparian vegetation type. Biomass (mg/m^3) of foliage invertebrates did not show any clear differences between 1981 and 1982 (Fig. 5.4-13). It was approximately the same in Riparian, Juniper, and Greasewood vegetation types, and lower in Shadscale vegetation type.

Table 5.4-9. Rankings of abundance (ind/m^3) of foliage invertebrates collected in sweep samples of 4 vegetation types, all hostplants together and big sagebrush only. Abundances are means for all months, 1981 and 1982. Ranks were tested with Newman-Keuls multiple comparison test (Zar 1974) on log (X+1) transformation. Ranks which are not significantly different ($p < 0.05$) are shown connected by lines.

	Vegetation Type	Abundance
All Hostplants	Riparian	225.0
	Greasewood	108.4
	Juniper	91.7
	Shadscale	46.4
Big Sagebrush	Riparian	288.2
	Greasewood	118.5
	Juniper	69.5
	Shadscale	53.7

Table 5.4-10. Mean abundance (ind/m³) ± standard deviation of foliage invertebrates (all hostplants combined), collected in sweep samples from April to October in 1981 and 1982. The 8 hostplants are shown in Table 5.4-8.

	yr	April	May	June	July	August	September	October	Mean
Greasewood	81	12±13	75±83	164±165	57±125	31±41	18±17	79±132	62±52
	82	16 74	81 164	427 1401	213 642	44 55	207 383	119 183	158 141
Juniper	81	14 18	90 95	132 135	48 95	26 52	35 69	96 360	63 43
	82	66 192	80 77	222 189	91 60	240 461	226 368	38 35	138 88
Shadscale	81	53 283	42 55	86 115	24 30	8.7 18	14 24	15 29	35 28
	82	5.0 12	55 76	113 137	76 75	64 84	45 57	39 47	57 34
Mean-Upland Habitats	81	26 23	69 24	127 39	43 17	22 12	22 11	63 43	53 16
	82	29 33	72 15	254 160	227 75	116 108	159 99	65 46	118 54
Riparian	81	26 20	111 347	164 155	186 154	45 68	30 79	170 282	105 70
	82	25 58	156 246	348 428	1006 3619	251 784	303 280	187 154	325 318
Mean-All Habitats	81	26 19	80 29	137 37	79 73	28 15	24 10	90 64	66 29
	82	28 27	93 44	278 138	346 444	150 111	195 108	96 72	169 113

Table 5.4-11. Mean abundance (ind/m³) ± standard deviation of foliage invertebrates on big sagebrush in different vegetation types. S corresponds to sweep samples, B corresponds to beat samples.

	yr	April	May	June	July	August	September	October	Mean
Greasewood	81S	13±13	87±90	172±163	40±49	39±50	19±16	32±48	57±56
	82S	28 103	137 218	756 1941	117 168	49 64	228 221	135 220	207 251
	82B	127 217	1302 1286	618 453	779 1354	274 199	441 273	1549 1174	727 527
Juniper	81S	14 14	114 102	148 102	39 39	25 26	34 42	33 36	58 51
	82S	21 40	81 65	156 170	68 48	57 47	112 119	34 28	76 46
	82B	177 161	1193 921	529 291	655 435	442 283	540 414	870 375	629 325
Shadscale	81S	16 18	45 63	96 107	27 29	17 23	14 16	23 31	34 29
	82S	5.8 14	88 91	170 170	90 45	104 102	35 30	55 53	78 53
	82B	117 120	721 448	1362 1330	1028 928	394 339	934 803	1275 969	833 455
Mean-Upland Habitats	81S	14 1.5	82 35	139 39	36 7.5	27 11	22 11	30 5.7	50 14
	82S	18 12	102 30	361 343	92 24	70 30	125 97	75 53	120 75
	82B	141 32	1072 309	837 457	821 190	370 87	638 261	1231 342	730 102
Riparian	81S	25 20	156 422	195 169	165 145	76 83	56 108	171 238	121 67
	82S	36 69	189 271	403 350	1463 4397	330 957	275 183	214 172	416 478
	82B	177 232	534 835	3510 4590	3873 7591	959 2441	1669 1393	3427 2906	2021 1554
Mean-All Habitats	81S	17 5.6	100 47	153 42	68 65	39 26	31 19	65 71	68 37
	82S	23 13	124 50	371 281	435 686	135 133	162 109	110 82	194 160
	82B	150 32	938 369	1505 1388	1588 1534	517 303	396 558	1780 1133	1053 651

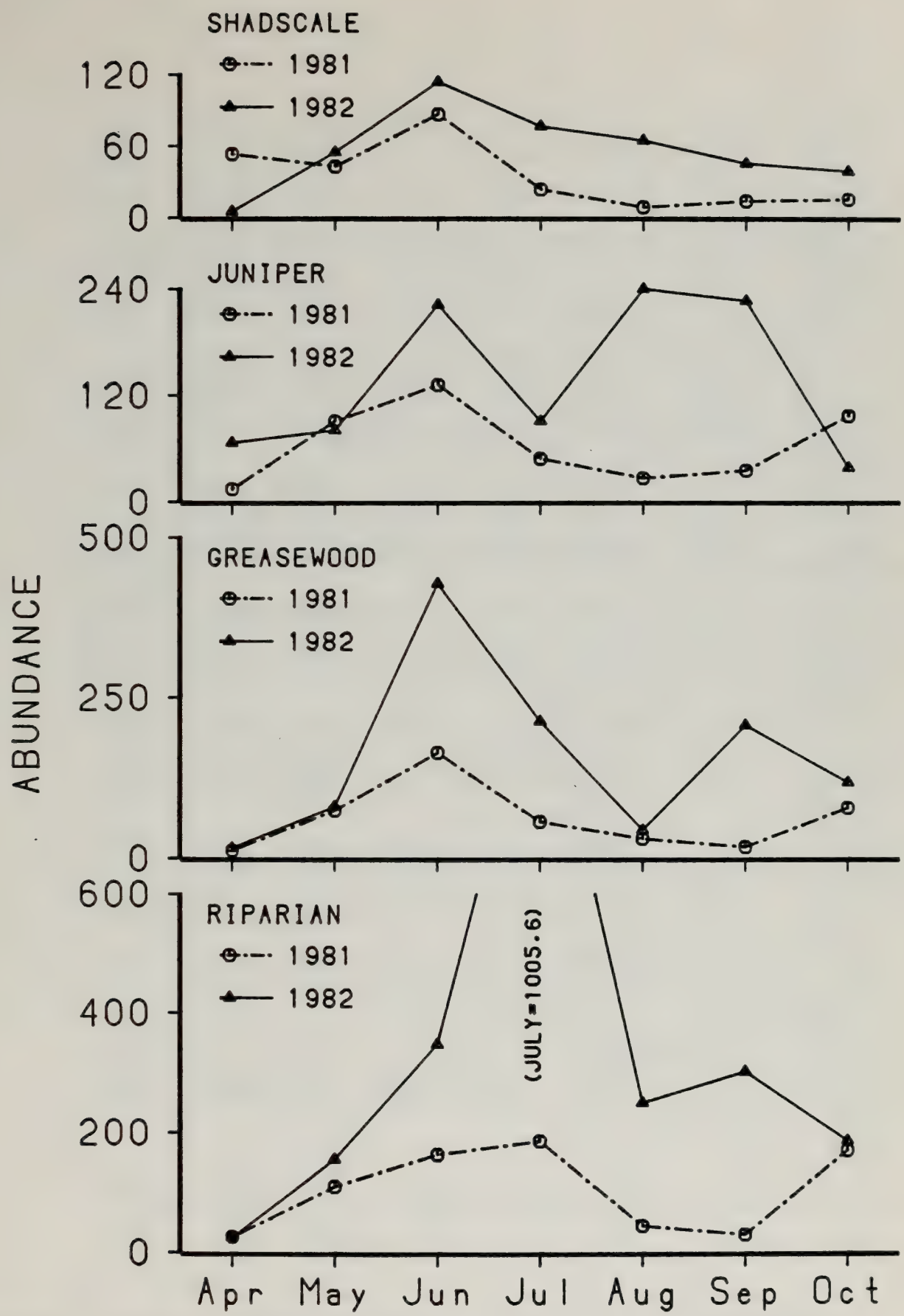


Fig. 5.4-12. Foliage invertebrate abundance (ind/m^3) in four vegetation types each month from April to October in 1982 and 1982. Data are from sweep samples for all hostplants combined.

Table 5.4-12. Family-level richness (R) and Shannon-Wiener diversity (H') on big sagebrush in 4 vegetation types, from April to October in 1981 and 1982. H' was calculated using abundance (ind/m³) of families. Number of replicates was not equal (see Table 5.4-4).

	yr.	April		May		June		July		August		September		October		Mean	
		R	H'	R	H'	R	H'	R	H'	R	H'	R	H'	R	H'	R	H'
Greasewood	81S	35	2.68	36	2.04	43	2.29	37	2.48	22	2.17	21	2.13	15	2.09	30	2.27
	82S	11	1.16	26	2.10	39	1.37	24	1.36	39	2.71	44	1.83	30	1.84	30	1.67
	82B	22	2.26	37	2.10	51	2.35	47	1.84	44	2.65	48	2.17	49	2.13	43	2.14
Juniper	81S	17	2.34	35	1.92	34	2.33	27	2.40	16	2.26	19	2.50	13	2.08	23	2.26
	82S	6	1.68	19	2.34	27	2.45	22	1.73	24	2.27	27	2.03	18	1.99	20	2.07
	82B	14	1.67	36	2.47	32	2.25	28	1.65	29	2.27	36	2.10	32	2.32	30	2.10
Shadscale	81S	24	2.61	26	1.81	31	2.45	19	2.41	14	2.29	10	1.38	10	1.74	19	2.09
	82S	5	1.30	21	2.39	31	1.78	25	1.53	25	2.22	16	1.57	14	1.31	20	1.73
	82B	16	2.00	35	2.54	45	1.66	43	1.40	37	2.55	40	2.22	42	2.19	37	2.07
Mean-Upland Habitats	81S	25	2.54	32	1.92	36	2.36	28	2.43	17	2.24	17	2.00	13	1.97	24	2.11
	82S	7	1.38	22	2.28	32	1.87	24	1.51	29	2.40	29	1.81	21	1.71	24	1.82
	82B	17	1.98	36	2.36	43	2.09	39	1.63	37	2.49	41	2.16	41	2.21	36	2.10
Riparian	81S	26	2.47	32	1.65	38	2.24	38	2.03	13	1.41	16	1.38	16	1.73	26	1.84
	82S	13	1.67	32	2.07	45	1.98	47	0.83	33	1.24	39	2.29	33	1.96	36	1.72
	82B	17	1.84	36	1.76	55	1.36	57	1.44	45	1.85	46	2.01	55	1.85	44	1.73
Mean-All Habitats	81S	26	2.53	32	1.86	37	2.33	30	2.33	16	2.03	17	1.85	14	1.91	24	2.12
	82S	9	1.45	25	2.23	36	1.90	30	1.34	30	2.11	32	1.93	24	1.78	27	1.80
	82B	17	1.94	36	2.21	46	1.91	44	1.58	39	2.33	43	2.13	45	2.12	38	2.01

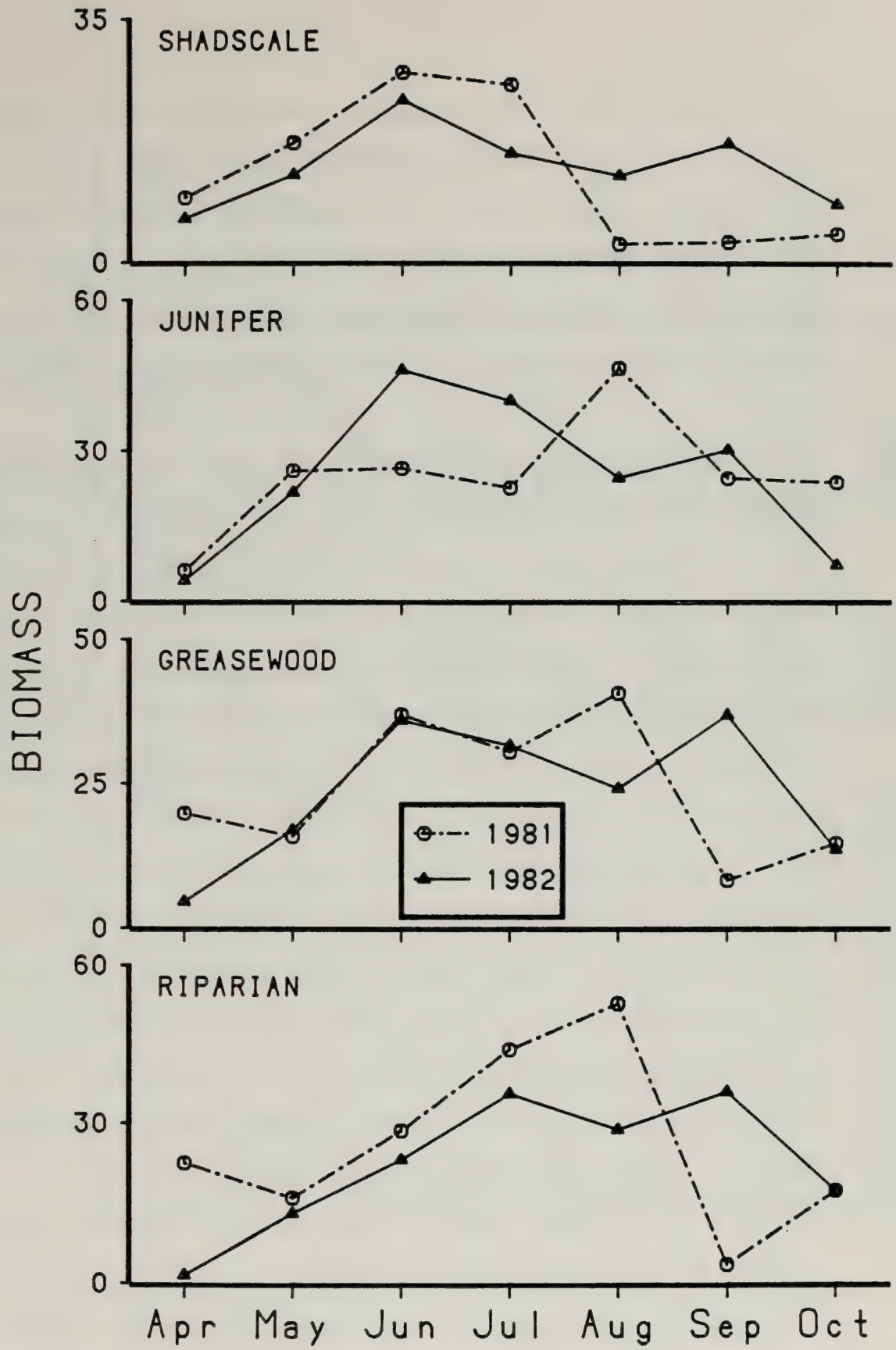


Fig. 5.4-13. Mean biomass (mg/m^3) of foliage invertebrates in 4 vegetation types each month from April to October in 1981 and 1982. Data are from sweep samples for all hostplants combined.

Abundance (ind/m^3) of sap feeders, predators, omnivores, and Diptera showed the same pattern across vegetation types as total foliage invertebrate abundance shown in Fig. 5.4-12. These groups were greatest in abundance in Riparian, followed by Greasewood, Juniper, and Shadscale vegetation types (Fig. 5.4-14). Abundance of leaf-chewers, parasites, and decomposers were greatest in Juniper, followed by Riparian, Greasewood, and Shadscale (Fig. 5.4-14).

5.4.2.5 Sweeping-Beating Comparison The mean foliage invertebrate abundance (ind/m^3) on big sagebrush in all vegetation types for sweep samples was 195.5 and for beat samples it was 1064.9. Thus capture rate was increased 5.4 times using beating methods with no increase in field time. Another important aspect of the abundance comparison was the coefficient of variation or CV (Zar 1974). Using untransformed data the CV for the sweep samples was 4.8, and for beat samples it was 2.0. Using log (X+1) transformed data the CV for sweep samples was 4.0, and for beat samples it was 0.2. Thus, in either case, the beating technique reduced the CV by a factor of at least two, which would enable one to statistically detect changes of smaller magnitude. Mean family-level richness for the sweep samples was 27 and for the beat samples it was 40. Finally, the mean family-level diversity (H') for the sweep samples was 1.78, and for the beat samples it was 2.01. Thus, estimates of abundance, richness, and diversity were all increased using the beating method, and statistical variability of abundance was decreased.

5.4.2.6 Discussion Abundance and richness of foliage invertebrates increased dramatically between 1981 and 1982, on all hostplants and in all vegetation types. Soil moisture was consistently greater in 1982. Thus it appears that abundance and richness may reflect changes in water conditions,

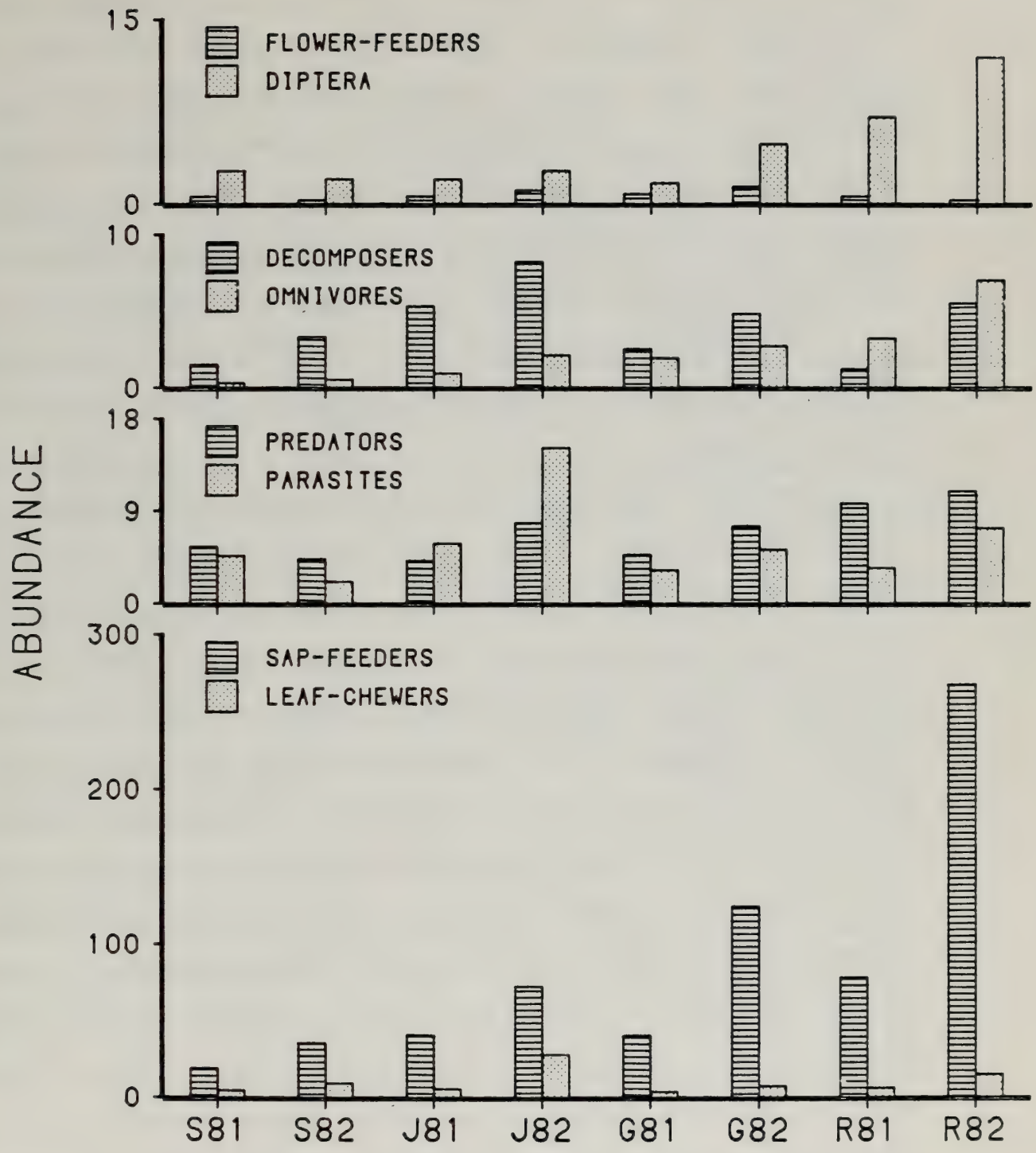


Fig. 5.4-14. Mean abundance (ind/m^3) of foliage invertebrates in 8 functional groups, in 4 vegetation types. Data are from sweep samples for all hostplants combined, 1981 and 1982.

along with plant biomass. Ironically, biomass of foliage invertebrates showed no difference between years. This may mean that certain groups with very low biomass (e.g., aphids, thrips) increased from 1981 to 1982, but others with greater biomass (e.g., grasshoppers, beetles) showed little or no change. One of our future goals is to assess the sensitivity of various foliage invertebrate taxa to environmental changes (between years, months, vegetation types, and hostplants), and to determine their usefulness as indicator taxa.

5.4.3 Amphibians and Reptiles Only one amphibian was seen on Tracts Ua and Ub in 1982: Woodhouse's toad (*Bufo woodhousei*). This was seen in the Riparian in August.

Estimates of reptile populations in all habitats were conducted in June, historically the month of highest overall reptile abundance. Climate is probably the most important factor influencing reptile population changes and the severity of a particular winter and subsequent spring thaw and early summer warmth affect reptile abundance. The winter of 1982 was only about 3°C colder than average, but it was significantly wetter than 1981 with almost 2.5 more inches of precipitation during the 6 months prior to June sampling. Most of this precipitation fell in the winter, whereas the spring was unusually dry (Fig. 5.2-1). Spring temperatures during 1982 were slightly cooler with maximum and minimum temperatures during June 1982 approximately 5°C colder than in 1981. Cumulative degree-days using total degrees above 15°C for each calendar day from 1 January to 30 June were calculated for 1981 and 1982. By June 1981, 284 degree-days had accumulated as compared to only 154 for the same 6 month period in 1982. This decrease in the amount of available heat was paralleled by an overall decline in lizard sightings of about 20%. Species richness and diversity in all habitats remained almost unchanged.

Six species of lizard and 2 species of snake were recorded on the tracts. All lizard species present in June 1981 were also present in June 1982 and included: eastern fence lizard (Scoloporus undulatus), tree lizard (Urosaurus ornatus), side-blotched lizard (Uta stansburiana), sagebrush lizard (Sceloporus graciosus), western whiptail (Cnemidophorus tigris), and short-horned lizard (Phrynosoma douglassi). In June 1981, the only snake encountered on transects was the midget-faded rattlesnake (Crotalus viridis concolor). In June 1982, no rattlesnakes were observed on transects but both the desert striped whipsnake (Masticophis taeniatus) and yellow-bellied racer (Coluber constrictor) were recorded. Because few snakes and no amphibians were recorded on the flushing transects, any conclusions concerning abundance for these species must be based on opportunistic sightings.

Reptile abundance in 1982 in both Greasewood and Shadscale habitats (Figs. 5.4-15 and 5.4-16) declined only slightly (means declined 12% and 7%, respectively) from 1981 abundance levels. In Juniper, however, mean reptile abundance was 46% below the 1981 level (Fig. 5.4-17). This rather large decrease in abundance may in part be due to inclement weather at the time of the June sampling. Daily minimums at that time were still near 5°C and daily maximums reached only 22°C. The Juniper habitat has sparse plant cover and shallow soils and, consequently, a low ability to buffer climatic extremes. The cold temperatures result in diminished lizard activity levels, which would make it appear as though population densities had decreased. An analysis of lizard data form 1975-1981 showed that when temperatures were below 15°-16°C the number of lizards seen on transects was depressed compared to days when temperatures were above 16°C.

In the Riparian habitat, mean reptile abundance in 1982 was 33% greater

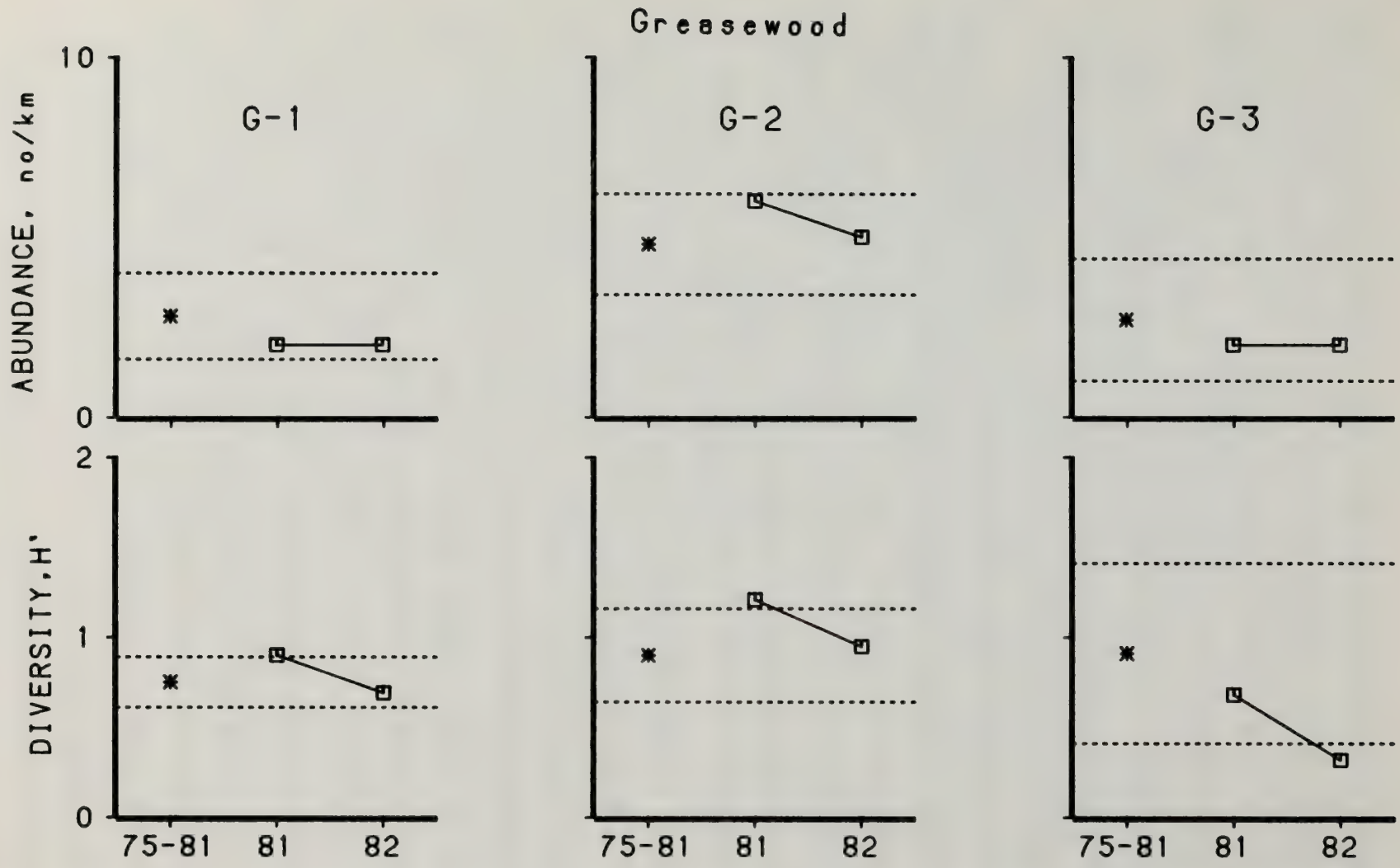


Fig. 5.4-15. Abundance (ind/km) and diversity (H') of reptiles in Greasewood in June 1981 and 1982, compared to means in June during the baseline period (1975-1981). 95% confidence limits of the baseline data are horizontal broken lines.

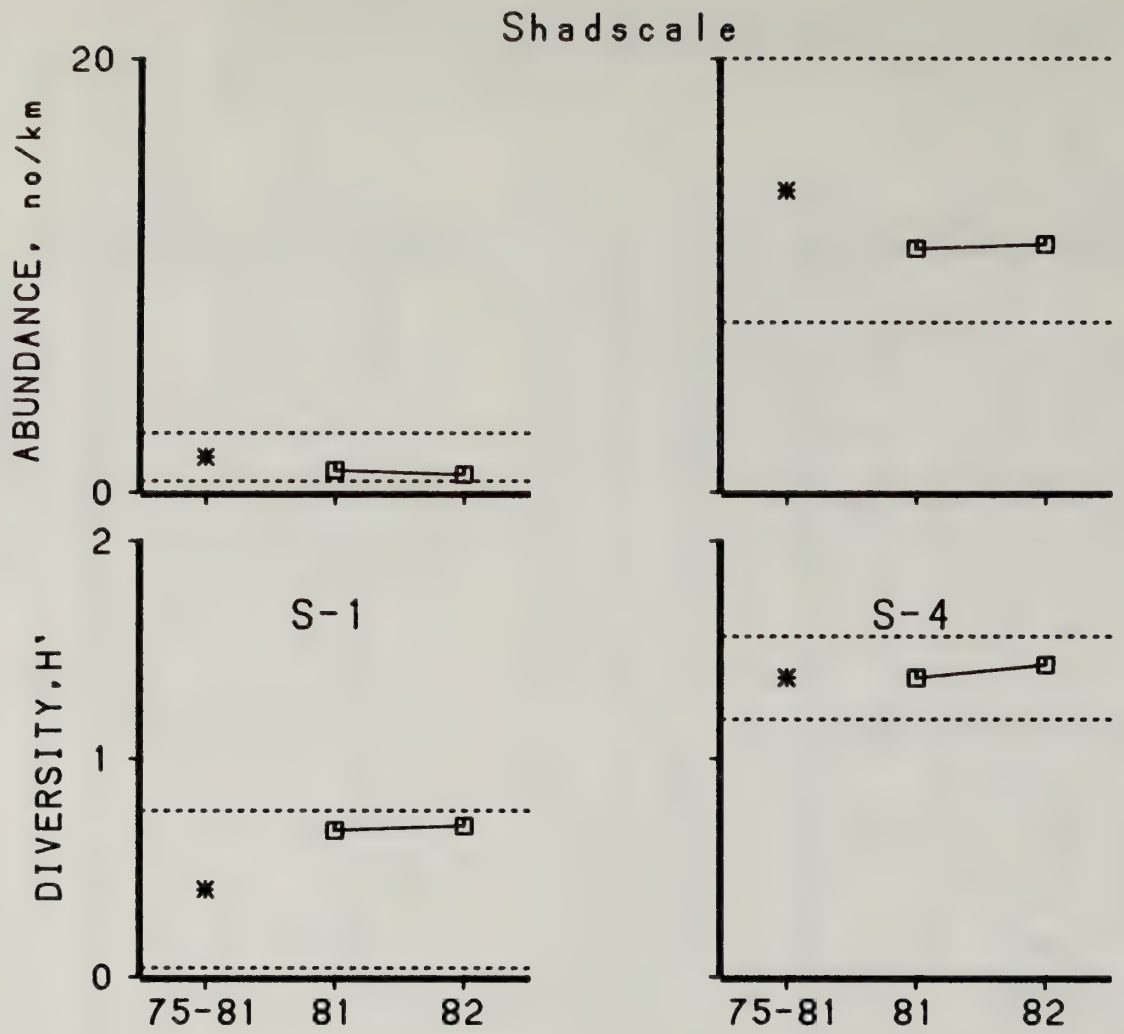


Fig. 5.4-16. Abundance (ind/km) and diversity (H') of reptiles in Shadscale in June 1981 and 1982, compared to means in June during the baseline period (1975-1981). 95% confidence limits of the baseline data are horizontal broken lines.

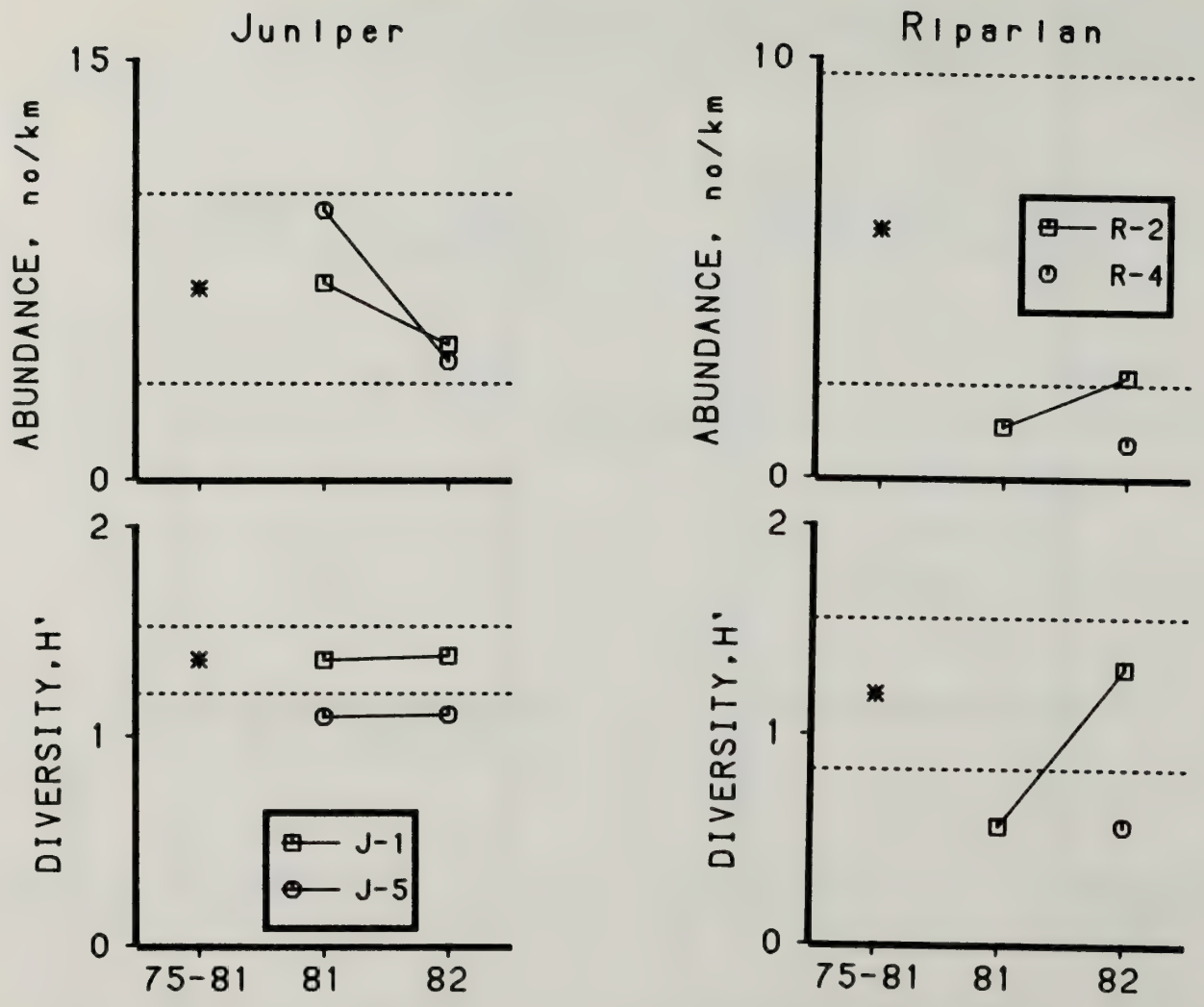


Fig. 5.4-17. Abundance (ind/km) and diversity (H') of reptiles in Juniper and Riparian in June 1981 and 1982, compared to means in June during the baseline period (1975-1981). 95% confidence limits of the baseline data are horizontal broken lines.

than in 1981, back within the 7-year, 95% confidence limits (Fig. 5.4-17). The wide confidence limits on abundance in riparian indicate erratic between-year variation. Although some of this variation is undoubtedly due to differing conspicuousness of lizards depending on the amount of herbaceous ground cover, there is no consistent relationship between biomass of annual plants and lizards seen on transect ($r=0.48$, $p=0.10$). The R-4 transect apparently has lower lizard abundance than R-2 (Fig. 5.4-17). Lizard species richness and diversity stayed within or returned to within 95% confidence intervals on most transects. Some changes between 1981 and 1982, however, were noted. In Greasewood diversity declined between 1981 and 1982 on all 3 transects. This was an artifact of the lower abundance in 1982; the rarer species simply were not seen although they probably were still present. On the other hand, diversity on R-2 increased sharply between 1981 and 1982, and came back within the 95% confidence limits. The causes of low diversity in 1981 on R-2 are unknown.

5.4.4 Birds Results of monitoring bird communities are divided into 6 sections: winter birds, spring birds, summer (breeding) birds, raptors, threatened and endangered species, and waterfowl.

5.4.4.1 Winter Bird Community The winter bird community on Tracts Ua and Ub has been highly variable from 1975 to 1982. Variation in February was not only high among years (consuming biomass ranged from 128 g/20 ha in 1980 to 1241 g/20 ha in 1976, means across 4 habitats), but also across habitats (157 g/20 ha in Shadscale to 734 g/20 ha in Riparian, mean over 8 years). Differences in community consuming biomass among years and habitats were not significant ($F_{7,20}=1.32$, $p=0.29$ for years; $F_{3,20}=1.05$, $p=0.39$ for habitats).

High variability results form the fact that many species forage in flocks

in the winter. For example, rosy finches (Leucosticte arctoa) usually found in flocks, were the most abundant species in Greasewood and Juniper in February 1982 (112 ind/20 ha in Greasewood, 105 ind/20 ha in Juniper, Table 5.4-13). Previous high density in February, for this species in Greasewood was 57 ind/20 ha in 1976 and in Juniper it was 88 ind/20 ha in 1977. The second most abundant species in 1982 was the pinyon jay (Gymnorhinus cyanocephalus)(33.5 ind/20 ha in Juniper), another species, that forages in flocks. Because of the patchy distribution of flocking species, they are usually encountered in high numbers or not at all, resulting in high variability.

Because of the high density of rosy finches in 1982, the February 1982 bird community was heavily dominated by granivores (Table 5.4-14). A large contribution by omnivores in Juniper represents pinyon jays.

5.4.4.2 Spring Bird Community The spring bird community, unlike that in winter, showed significant differences among years ($F_{7,21}$=2.28, p=0.07 for consuming biomass). Consuming biomass in April 1982 was significantly higher than that in April 1981.

The April bird communities were dominated by ground foragers including granivores, omnivores, and insectivores (Table 5.4-15). Several insectivore guilds that are usually present in spring were not recorded during April 1982, but this is likely due to the much reduced sampling effort in April 1982 (three days on four transects). Because of the lack of sighting of some of the rarer species, we will return to a full sampling regime (five days on eight transects) in 1983.

The most common species during April was dark-eyed junco (Junco hyemalis)(19.4 ind/20 ha in Greasewood, 15.2 ind/20 ha in Juniper, 42.5 ind/20 ha in Riparian; Table 5.4-13), a migratory species not usually present in

Table 5.4-13. Bird species of the Utah Oil Shale Tracts, Ua and Ub in 1982. Species are divided into raptors, aquatic species (abundance presented as ind/km for both) and terrestrial species (density presented as ind/20 ha). Species present but not on transects are denoted by "X". Abundance for aquatic species in April are from a canoe transect on the White River.

Species	Habitat*	February	April	June
RAPTORS				
Turkey Vulture	S			0.2
Cathartes aura	R		X	
Golden Eagle	G		X	0.2
Aquila chrysaetos	J		X	0.1
	S		X	
	R		X	
Bald Eagle	S	X	X	
Haliaeetus leucocephalus	R		X	
Cooper's Hawk	J	X		
Accipiter cooperii	R		0.3	0.3
Sharp-shinned Hawk	R			X
Accipiter striatus				
Northern Harrier	G	X		
Circus cyaneus	S		X	
	R		X	
Red-tailed Hawk	J		0.1	
Buteo jamaicensis	S	X	X	0.2
	R		0.3	1.0
Prairie Falcon	G		X	
Falco mexicanus	S	X		
	R		X	X
American Kestrel	G		0.1	0.1
Falco sparverius	J		0.1	0.1
	S		X	0.3
	R	X	X	0.7

Table 5.4-13 (Continued)

Species	Habitat*	February	April	June
RAPTORS (cont,)				
Great Horned Owl *Bubo virginianus*	R		X	X
Long-eared Owl *Asio otus*	R		X	X
AQUATIC SPECIES				
Canada Goose *Branta canadensis*	R	X	1.73	X
Mallard *Anas platyrhynchos*	R		0.37	
Gadwall *Anas strepera*	R		0.14	
American Wigeon *Anas americana*	R		0.07	
Northern Shoveler *Anas clypeata*	R		0.06	
Lesser Scaup *Aythya affinis*	R		0.07	
Blue-winged Teal *Anas discors*	R		0.05	
Green-winged Teal *Anas crecca*	R		0.53	
Cinnamon Teal *Anas cyanoptera*	R		0.03	
Common Merganser *Mergus merganser*	R	X	0.03	
Red-breasted Merganser *Mergus serrator*	R		0.05	

Table 5.4-13 (Continued)

Species	Habitat*	February	April	June
AQUATIC SPECIES (cont.)				
Great-blue Heron *Ardea herodias*	R		0.01	
Sandhill Crane *Grus canadensis*			Flying over all habitats	
Killdeer *Charadrius vociferus*	R		0.01	0.1
Spotted Sandpiper *Actitis macularia*	R			0.01
Common Snipe *Gallinago gallinago*	R		X	
TERRESTRIAL SPECIES				
Chukar *Alectoris chukar*	R			X
Ring-necked Pheasant *Phasianus colchicus*	R		X	
Mourning Dove *Zenaida macroura*	G J S R			0.4 0.8 0.5 1.5
Yellow-billed Cuckoo *Coccyzus americanus*	R			0.3
Common Nighthawk *Chordeiles minor*	S R			0.5 X
White-throated Swift *Aeronautes saxatalis*	G J R		X X X	 4.0
Black-chinned Hummingbird *Archilochus alexandri*	J R			0.8 X

Table 5.4-13 (Continued)

Species	Habitat*	February	April	June
TERRESTRIAL SPECIES (cont.)				
Belted Kingfisher	R		X	X
Ceryle alcyon				
Common Flicker	G	X	X	
Colaptes auratus	J	0.4	0.5	
	S		0.5	
	R	X	1.6	0.9
Hairy Woodpecker	R	0.7	X	
Picoides villosus				
Downy Woodpecker	R		2.1	0.8
Picoides pubescens				
Western Kingbird	R			0.3
Tyrannus verticalis				
Ash-throated Flycatcher	G			0.2
Myiarchus cinerascens	S			0.7
	R			6.7
Say's Phoebe	G		X	0.2
Sayornis saya	J		X	0.2
	S			1.0
	R		X	4.7
Willow Flycatcher	R			5.0
Empidonax traillii				
Gray Flycatcher	J			0.9
Empidonax wrightii				
Western Wood Peewee	R			1.3
Contopus sordidulus				
Horned Lark	G		X	
Eremophila alpestris	S	0.3	X	X
	R		X	
Violet-green Swallow	G			0.3
Tachycineta thalassina	J			0.2

Table 5.4-13 (Continued)

Species	Habitat*	February	April	June
TERRESTRIAL SPECIES (cont.)				
Cliff Swallow	S			7.1
Hirundo pyrrhonota	R			176.5
Common Raven	G	0.2	X	
Corvus corax	S	X	X	
American Crow	S		X	
Corvus brachyrhynchos	R			X
Black-billed Magpie	G		X	X
Pica pica	J	X	X	
	R	X	X	
Pinon Jay	G	0.4	14.4	0.1
Gymnorhinus cyanocephalus	J	33.5	24.7	0.5
	R		X	
Clark's Nutcracker	J	X	X	
Nucifraga columbiana	R			X
Black-capped Chickadee	S	X		
Parus atricapillus	R	0.6	3.4	2.9
Mountain Chickadee	R	X		
Parus gambeli				
Plain Titmouse	J	1.6	X	0.4
Parus inornatus				
Bushtit	J	7.4	X	
Psaltriparus minimus	R	1.0		
White-breasted Nuthatch	R			0.4
Sitta carolinensis				
House Wren	R			3.3
Troglodytes aedon				
Bewick's Wren	G			X
Thryomanes bewickii	J	X	X	0.9

Table 5.4-13 (Continued)

Species	Habitat*	February	April	June
TERRESTRIAL SPECIES (cont.)				
Long-billed Marsh Wren	G	X		
Cistothorus palustris				
Canon Wren	G		X	X
Catherpes mexicanus	J	X	X	0.3
	S	0.3		
Rock Wren	G		X	2.3
Salpinctes obsoletus	J		X	1.7
	S		X	1.6
	R	X		X
Gray Catbird	R			X
Dumetella carolinensis				
Sage Thrasher	G		X	
Oreoscoptes montanus	S		X	X
American Robin	G		X	
Turdus migratorius	J	X	0.7	
	S	X		
	R		X	2.5
Mountain Bluebird	G		3.2	0.2
Sialia currucoides	J	X	2.2	1.2
	S		X	0.2
	R		4.9	10.3
Townsend's Solitaire	G		0.6	
Myadestes townsendi	J		X	
Blue-gray Gnatcatcher	G			0.9
Poliptila caerulea	J			5.1
	S			0.9
	R			9.0
Ruby-crowned Kinglet	R		1.4	
Regulus calendula				
Cedar Waxwing	R			5.1
Bombycilla cedrorum				

Table 5.4-13 (Continued)

Species	Habitat*	February	April	June
TERRESTRIAL SPECIES (cont.)				
Northern Shrike	J	X		
Lanius excubitor				
Loggerhead Shrike	G	X	X	X
Lanius ludovicianus	J		X	
	S		X	0.3
European Starling	S			X
Sturnus vulgaris	R	X	3.7	9.9
Solitary Vireo	R			0.4
Vireo solitarius				
Warbling Vireo	R			8.2
Vireo gilvus				
Vireo (unid)	R			0.4
Vireo sp.				
Yellow Warbler	R			22.2
Dendroica petechia				
Yellow-rumped Warbler	R			0.4
Dendroica coronata				
Black-throated Gray Warbler	G			0.6
Dendroica nigrescens	J			8.6
	R			0.4
MacGillivray's Warbler	R			0.8
Oporornis tolmiei				
Yellow-breasted Chat	R			4.5
Icteria virens				
Western Meadowlark	G		X	0.9
Sturnella neglecta	J			X
	S		6.3	2.7
	R		0.4	

Table 5.4-13 (Continued)

Species	Habitat*	February	April	June
TERRESTRIAL SPECIES (cont.)				
Red-winged Blackbird	R		X	0.7
Agelaius phoeniceus				
Scott's Oriole	G			X
Icterus parisorum	J			0.1
Northern Oriole	R			6.9
Icterus galbula				
Brown-headed Cowbird	J			0.6
Molothrus ater	R			18.2
Western Tanager	J			0.2
Piranga ludoviciana	R			2.9
Black-headed Grosbeak	R			3.5
Pheuticus melanocephalus				
Blue Grosbeak	R			X
Guiraca caerulea				
Lazuli Bunting	G			0.2
Passerina amoena	R			6.0
House Finch	G			1.6
Carpodacus mexicanus	J			7.4
	S			1.2
	R		57.5	32.4
Rosy Finch	G	112.0	X	
Leucosticte arctoa	J	105.4		
	S		X	
American Goldfinch	R	1.0		
Carduelis tristis				
Rufous-sided Towhee	G			0.5
Pipilo erythrophthalmus	R		6.8	20.2

Table 5.4-13 (Continued)

Species	Habitat*	February	April	June
TERRESTRIAL SPECIES (cont.)				
Lark Sparrow	G			0.3
Chondestes grammacus	J			0.3
	S			1.9
	R			10.9
Black-throated Sparrow	G			3.4
Amphispiza bilineata	J			3.7
	S			3.7
Sage Sparrow	G		2.3	1.4
Amphispiza belli	S		11.7	6.5
Dark-eyed Junco	G		19.4	
Junco hyemalis	J	X	15.2	
	S		X	
	R	20.1	42.5	
Chipping Sparrow	G			X
Spizella passerina	J			3.9
	R	X		
Brewer's Sparrow	G			5.8
Spizella breweri	J			1.0
	S			1.2
Song Sparrow	G	X		
Melospiza melodia	R	X	X	0.5
White-crowned Sparrow	R			0.5
Zonotrichia leucophrys				
Sparrow (unid)	G			0.2
	J			0.5
	S		0.8	0.5
	R		7.3	1.0

*G = Greasewood; J = Juniper; S = Shadscale; R = Riparian

Table 5.4-14. Consuming biomass (g/20 ha) of avian foraging guilds in February 1982 at the Federal Prototype Shale Oil Tracts, Ua and Ub.

Trophic Group*	Guild*	Vegetation Types			
		Greasewood	Juniper	Shadscale	Riparian
G	GGG	859.0	816.1	2.9	134.6
O	GGO	25.3	629.8	-	-
I		-	41.2	1.5	15.0
	BPI	-	-	-	9.2
	FGI	-	32.6	-	5.7
	GGI	-	8.6	1.5	-
TOTAL		884.3	1528.3	5.9	164.5

*see Table 5.4-16 for symbol definitions.

Table 5.4-15. Consuming biomass (g/20 ha) of avian foraging guilds in April 1982 on the Federal Prototype Shale Oil Tracts, Ua and Ub.

Trophic Group*	Guild*	Vegetation Types			
		Greasewood	Juniper	Shadscale	Riparian
G	GGG	140.2	98.0	81.0	699.7
O	GGO	270.8	464.0		70.0
I		33.7	40.6	124.6	180.0
	AHI	5.1			
	BPI				16.5
	FGI				19.4
	GGI	28.6	40.6	124.6	144.4
	TOTAL	444.7	602.6	205.6	950.0

*see Table 5.4-16 for symbol definitions.

June.

5.4.4.3 Breeding Bird Community June bird populations as measured by total community consuming biomass showed significant difference among years ($F_{7,21}$=2.36, p=0.06). Populations in the three upland habitats in 1982 were lower than the 1975-1981 mean. In Riparian they were higher than ever before (Fig. 5.4-18). Because of different types of change in different habitats, 1982 consuming biomass (mean of four habitats) was not significantly different from any other year (LSD, α =0.05).

The dramatic increase in consuming biomass in riparian habitat was due primarily to one species: cliff swallow (*Hirundo pyrrhonota*). Although the occurrence of this colonial nesting bird on Riparian transects has been erratic from 1975-1981, the dramatic increase in 1982 is partly due to the location of the new transect, R-4. Transect R-4 was near three colonies of cliff swallows, totaling 624 nests. Although R-4 is close to R-2, very few cliff swallows were seen on R-2. Community consuming biomass, excluding cliff swallows, remained essentially unchanged between 1981 and 1982 (Fig. 5.4-18).

Changes in functional groups (granivore, omnivore, and insectivore) were different in different habitats (Fig. 5.4-19, Fig. 5.4-20, Table 5.4-16). In Greasewood, all 3 groups declined. In Juniper, the decline was most pronounced within the insectivore group although granivores also declined. In Shadscale, consuming biomass of each group stayed approximately the same with omnivores not being represented in 1982. These 3 upland habitats showed little change in the percentage contribution of each functional group to the total community. However, in Riparian, the increase in the insectivores, which was primarily due to an increase in cliff swallows, resulted in a community more strongly dominated by insectivores than in previous years.

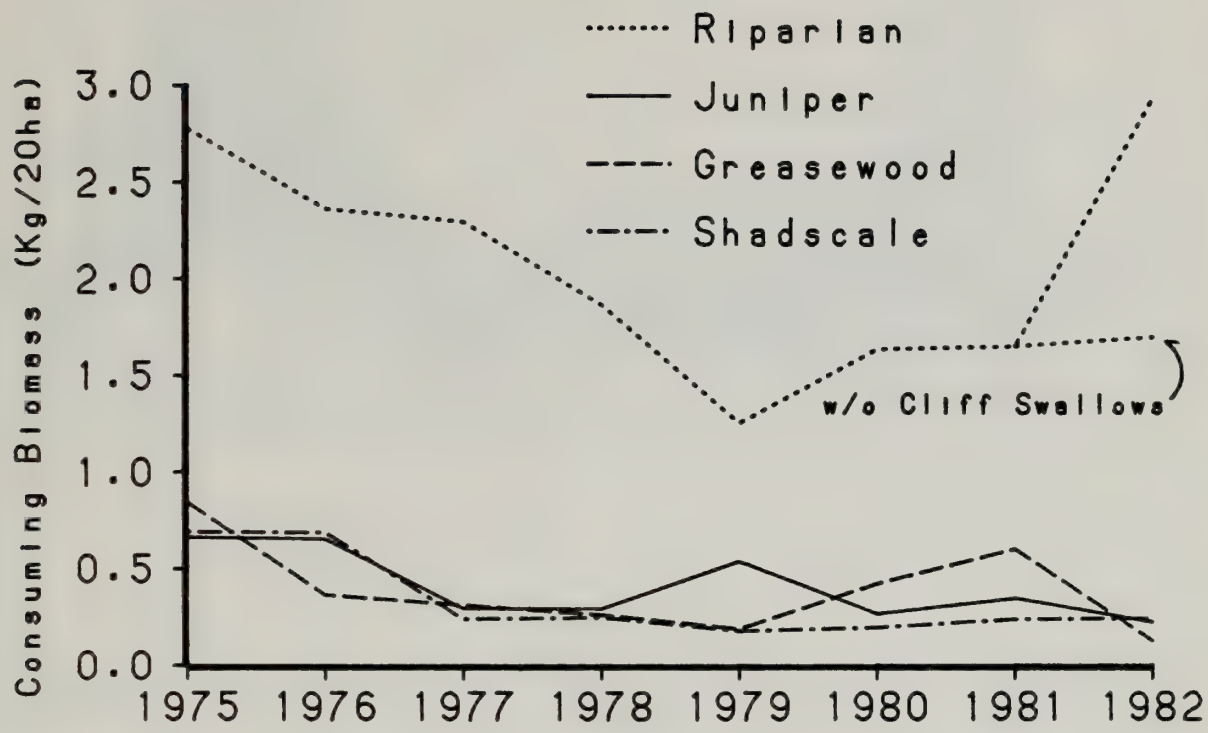


Fig. 5.4-18. Consuming biomass (kg/20 ha) of the bird community in June from 1975 through 1982 in four habitats.

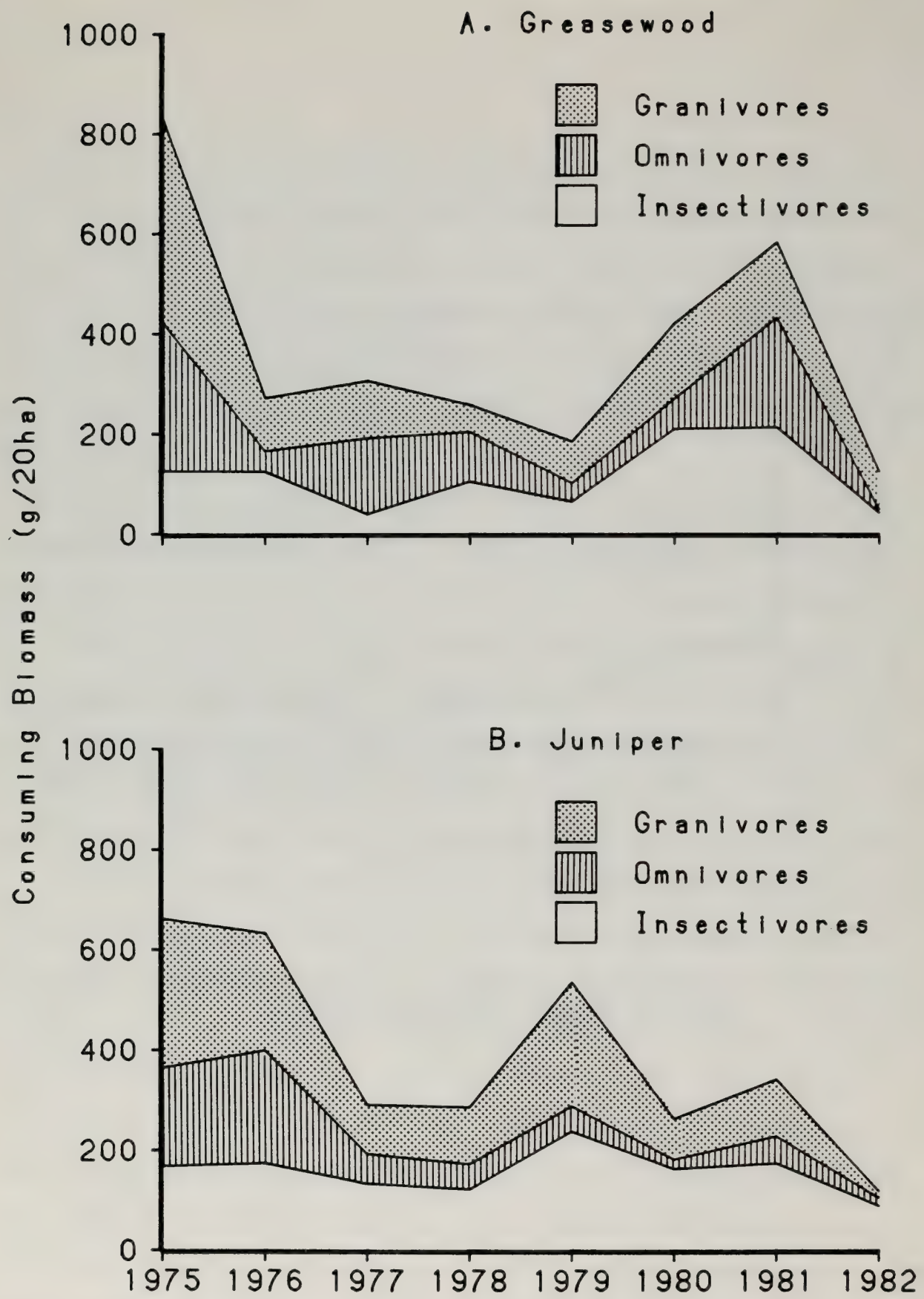


Fig. 5.4-19. Consuming biomass (kg/20 ha) of three trophic groups in June from 1975 through 1982 in Greasewood and Juniper.

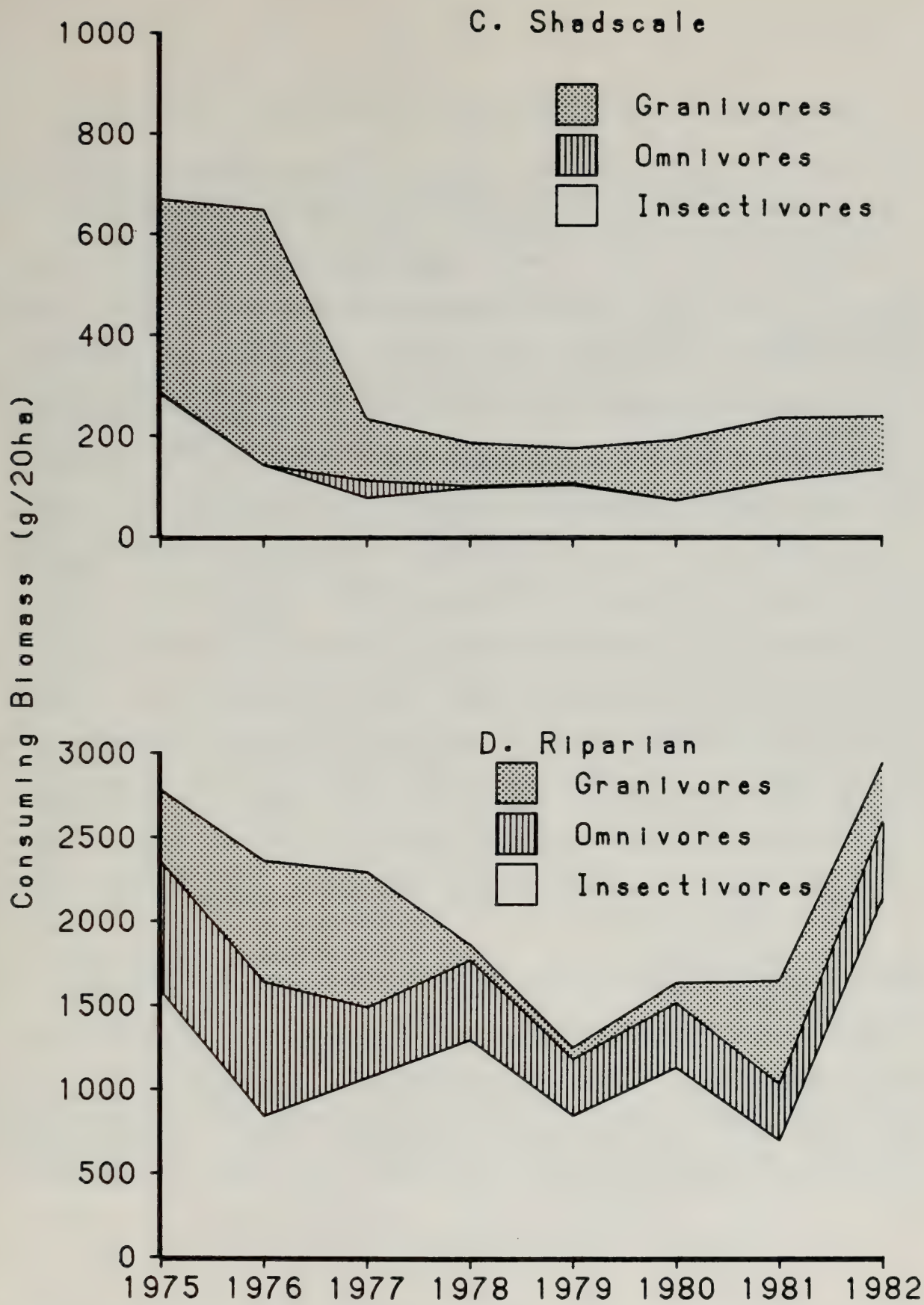


Fig. 5.4-20. Consuming biomass (kg/20 ha) of three trophic groups in June from 1975 through 1982 in Shadscale and Riparian.

Table 5.4-16. Consuming biomass (g/20 ha) of avian foraging guilds in June 1982 at the Federal Prototype Shale Oil Tracts, Ua and Ub.

Trophic Group*	Guild+	Vegetation Types			
		Greasewood	Juniper	Shadscale	Riparian
G	GGG	75.1	113.2	104.2	347.5
O	GGO	7.4	16.2	-	454.4
I		41.9	89.2	132.8	2133.6
	ACI	1.7	1.3	57.4	1284.9
	AHI	1.6	5.9	7.3	105.4
	BGI	-	3.7	-	17.9
	BPI	-	-	-	6.6
	FGI	7.1	56.7	8.6	410.3
	GGI	31.5	21.6	59.5	308.5
	N	-	1.6	-	-
	R	-	-	3.8	-
TOTAL		124.4	220.2	240.8	2935.5

*G = Granivore; O = Omnivore; I = Insectivore

+GGG = Ground-gleaning Granivore; GGO = Ground-gleaning Omnivore; ACI = Air-cruising Insectivore; AHI = Air-hawking Insectivore; BGI = Bark-gleaning Insectivore; BPI = Bark-probing Insectivore; FGI = Foliage-gleaning Insectivore; GGI = Ground-gleaning Insectivore; N = Nectarivore; R = Raptor (excluding hawks and owls).

Consuming biomass of granivores and omnivores in Riparian did not change markedly between 1981 and 1982.

In Greasewood, changes in the insectivore group between 1981 and 1982 were mostly due to a decline in ground-gleaning insectivores (Fig. 5.4-21, Table 5.4-16). The 3 dominant species of ground-gleaning insectivores in Greasewood were all lower in density in 1982 than in the 1975-1981 mean: rock wren (Salpinctes obsoletus), mean = 5.0±1.1 (SE), density in 1982 was 2.3 ind/20 ha; mountain bluebird (Sialia curucoides), mean = 2.8±1.3, density in 1982 was 0.2 ind/20 ha; western meadowlark (Sturnella neglecta), mean = 2.2±1.0, density in 1982 was 0.9 ind/20 ha.

The decline in the insectivore trophic group in Juniper between 1981 and 1982 was caused by a decline in all insectivore guilds. The most precipitous decline occured in plain titmouse (Parus inornatus)(2.1±0.9 to 0.4 ind/20 ha), gray flycatcher (Empidonax wrightii)(4.0±0.7 to 0.9 ind/20 ha) and an omnivore: pinyon jay (2.5±1.2 to 0.5 ind/20 ha). The apparent decrease in pinyon jays represents a shift in location of the flock more than a change in population density as other observations indicated numerous successful nests in 1982.

In Shadscale, the relative contribution of insectivore guilds to the insectivore trophic groups was similar to that observed in previous years (Fig. 5.4-22). Despite this constancy of the guilds in 1982, individual species in several guilds differed significantly from the 1975-1981 mean. Declines were observed for mourning doves (Zenaida macroura)(2.5±1.6 to 0.5 ind/20 ha) and loggerhead shrikes (Lanius ludovicianus)(1.5±0.7 to 0.3 ind/ha in 1982). Increases were observed for house finches (Carpodacus mexicanus)(0.2±0.1 to 1.2 ind/20 ha in 1982) and cliff swallows (0.4±0.3 to

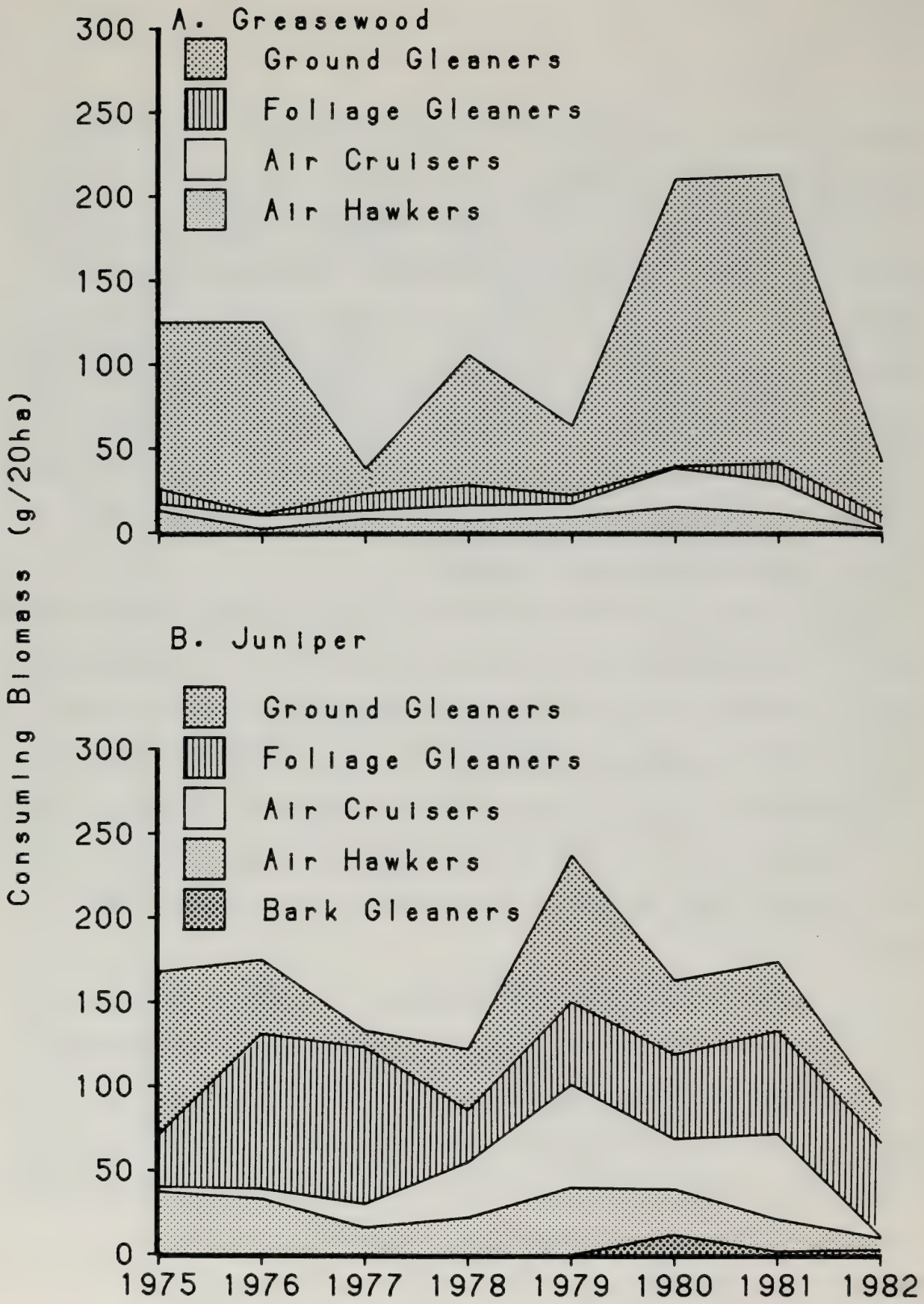


Fig. 5.4-21. Consuming biomass (kg/20 ha) of insectivore guilds in June from 1975 through 1982 in Greasewood and Juniper.

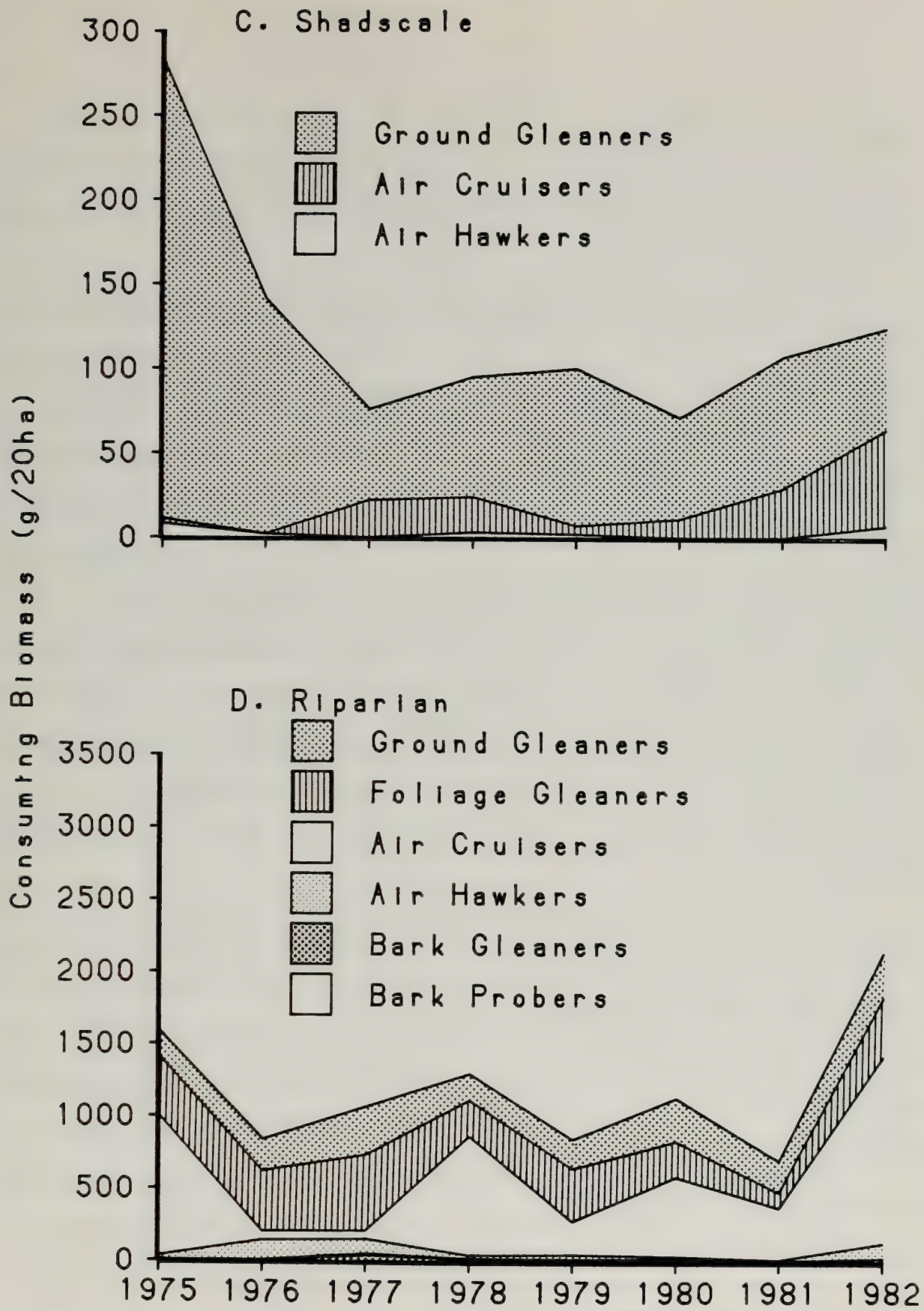


Fig. 5.4-22. Consuming biomass (kg/20 ha) of insectivore guilds in June from 1975 through 1982 in Shadscale and Riparian.

7.1 ind/20 ha in 1982). Although density of cliff swallows in Shadscale represents foraging birds and not breeding density, the high density corroborates evidence from the Riparian transects that overall populations of cliff swallows were high in 1982.

In Riparian, insectivore guild structure was changed primarily by an increase in air cruisers (Fig. 5.4-22). In addition to the increase in cliff swallows (58.8±17.7 to 176.5 ind/20 ha in 1982, Table 5.4-13) mentioned previously, increases were also seen in other insectivores: white-throated swift (Aeronautes saxatalis)(0.7±0.4 to 4.0 ind/20 ha in 1982), willow flycatcher (Empidonax trailii)(1.1±0.4 to 5.0 ind/20 ha), Say's phoebe (Sayornis saya)(0.3±0.1 to 4.7 ind/20 ha), MacGillivrays warbler (Oporornis tolmiei)(0.1±0.2 to 0.8 ind/20 ha), warbling vireo (Vireo gilvus)(1.0±0.5 to 8.2 ind/20 ha), common flicker (Colaptes auratus)(0.1±0.4 to 0.9 ind/20 ha), mountain bluebird (1.8±1.0 to 10.3 ind/20 ha), and European starling (Sturnus vulgaris)(2.4±0.6 to 9.9 ind/20 ha). At the same time one species, a granivore, decreased in density in Riparian (mourning dove, 4.1±1.0 to 1.5 ind/20 ha in 1982).

The generally low bird population in June 1982 in the three upland habitats can probably be attributed to a poor food resource resulting from low precipitation. Mean spring precipitaion in 1982 (3.5 cm) was lower than in any other year since 1975 (Fig. 5.2-1). Data from 1975 through 1981 showed a significant positive correlation between spring precipitation and consuming biomass of June bird cmomunities (WRSP 1981 Annual Report). It is presumed that the quantity of food resources available to birds is controlled by plant productivity which in turn is determined by the amount of spring precipitation.

Similarly, the high density of cliff swallows in Riparian has been found in the past to be positively correlated with peak water flow in the White River, a variable which is also expected to correspond to food availability. The peak flow in 1982 was not only high but was extended over a long period. Thus, the total community increase in Riparian is consistent with previously hypothesized relationships.

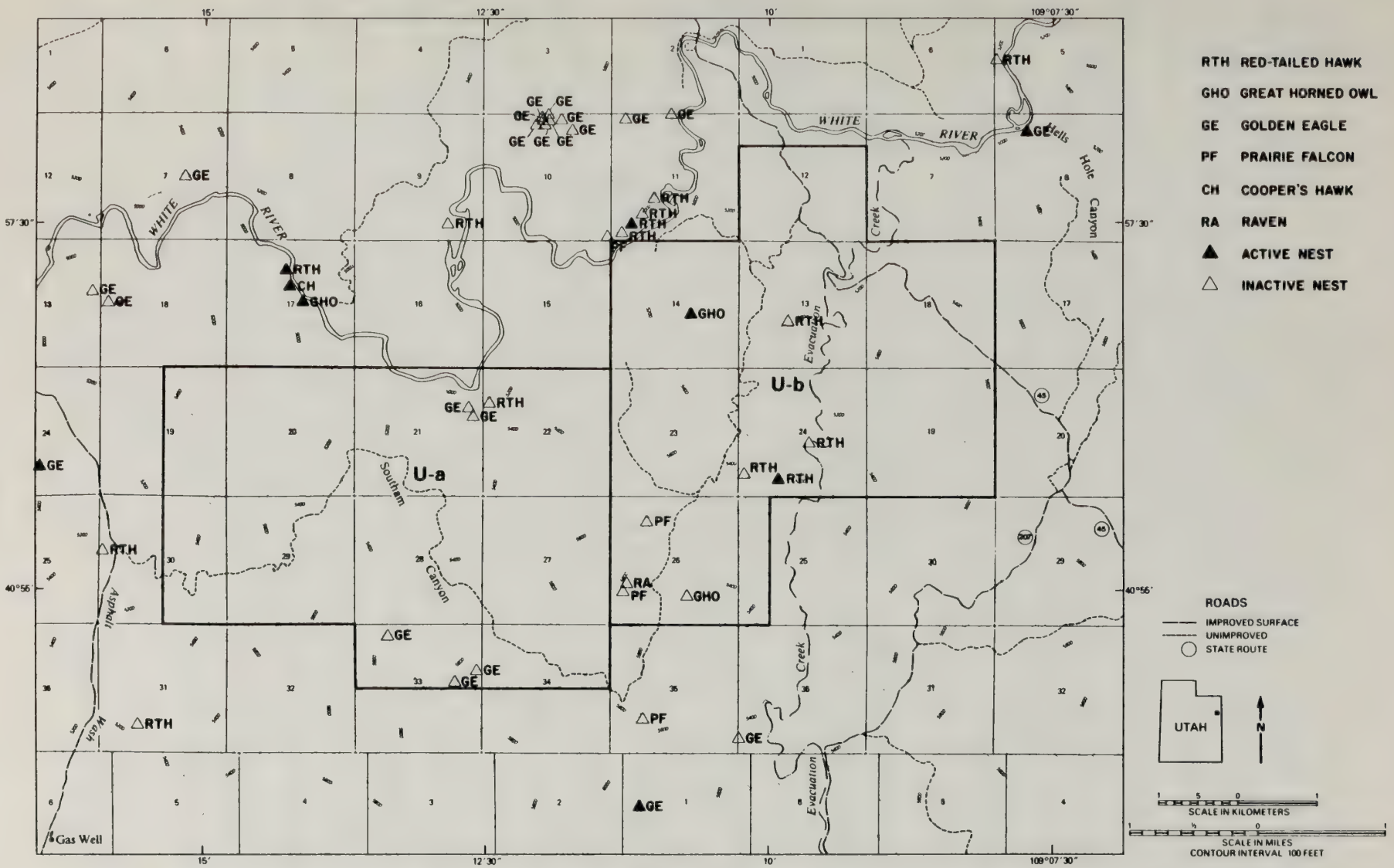
June 1982 sampling in Riparian revealed one species that had never before been seen on the site, gray catbird (Dumetalla carolinensis), and one species that had only been seen once, in 1977, yellow-bellied cuckoo (Coccyzus americanus).

5.4.4.4 Raptors A total of 58 raptor nests of 7 species were located on or near Tracts Ua and Ub during 1982 (Table 5.4-17; Fig. 5.4-23). Common raven (Corvus corax) nests are included in this total because ravens are partially predatory and their nests are often used by hawks or owls. Eleven active nests were located. Figure 5.4-23 does not include all nests because some are located off the map. Two inactive golden eagle (Aquila chrysaetos) nests and one active prairie falcon (Falco mexicanus) nest (that produced five young) were found along the White River upstream of nests shown in Fig. 5.4-23. Just north of Ignatio two red-tailed hawk (Buteo jamaicensis) nests and two great horned owl (Bubo virginianus) nests were located, all of which were inactive in 1982. Downstream on the White River, an additional five inactive golden eagle nests were found. All five were on high cliffs overlooking the White River. Also, an active long-eared owl (Asio otus) nest not shown in Fig. 5.4-23 was found in Riparian habitat near the mouth of Asphalt Wash.

Only three of 28 golden eagle nests were active in the 55 sq. mi. searched in 1982. This represents a breeding density of approximately one

Table 5.4-17. Raptor nests located on or near the Federal Prototype Shale Tracts, Ua and Ub during 1982. See Fig. 5.4-23 for nest locations.

Species	Active	Inactive
Golden Eagle	3	25
Prairie Falcon	1	4
Red-tailed Hawk	3	14
Cooper's Hawk	1	0
Great Horned Owl	2	3
Long-eared Owl	1	0
Raven	0	1
TOTAL	11	47



RAPTOR NEST LOCATIONS

Fig. 5.4-23. Sites of active and inactive raptor (hawks and owls) and raven nests in 1982. See legend for symbol definitions.

pair per 20 sq. mi. The three active nests were all located outside of the boundaries of Tracts Ua and Ub. All were in relatively inaccessable or remote sites: one, northeast of Ub was on an inaccessable cliff directly over the White River; another, south of Tracts Ua and Ub was near the top of a rock pinnacle about 2 km from the nearest road; the third was west of Ua on a cliff facing west, away from Asphalt Wash. None of the nests were visible from a road. Whether or not nest location was in response to activity on and near the roads is unknown. In any case, alternative nest sites that have been used in previous years are plentiful.

A large concentration of golden eagle nests (eight nests) were found on cliffs north of the White River in Section 10 (Fig. 5.4-23). Although a pair of eagles was seen in this vicinity in February, none of these nests were used in 1982. An active golden eagle nest was found 8 km to the northeast of these nests, in the vicinity of Bonanza. The pair using that nest may also use the nests in Section 10 in some years or this concentration of unused nests may represent a potential golden eagle territory that is not presently occupied.

Golden eagle abundance (mean of four habitats measured along flushing transects) in June 1982 was 0.08 per km, higher than in June of all previous years except 1975 (0.08) per km. However, no golden eagles were seen from transects in February or April 1982 whereas the 1975 through 1981 means were 0.11 for February and 0.05 for April. These apparent changes, however, may only represent shifts in location as golden eagles have large home ranges.

The red-tailed hawk was the second most common breeding raptor on the site (three active plus 14 inactive nests, Table 5.4-17). Many of the inactive nests were quite old and may have been made or used by other species. Red-tailed hawk nests were found both on cliffs and in cottonwood trees in

Riparian habitat. Red-tailed hawk abundance measured along flushing transects in June 1982 (mean for 4 habitats=0.30) was higher than the highest value during 1975-1981 (0.08 in 1978). This resulted from the fact that the R-4 transect was close to an active nest so that sightings were much more frequent than in previous years.

Other active nests found on the site were prairie falcon (one nest on cliffs near the White River northeast of Ub), Cooper's hawk (Accipiter cooperii)(one nest in riparian habitat), great horned owl (two nests), and long-eared owl (one nest in riparian habitat).

5.4.4.5 Threatened and Endangered Species The bald eagle (Haliaetus leucocephalus) survey was conducted by helicopter on 12 February 1982. Ten bald eagles were counted, all along the White River. Three bald eagles were west of the proposed White River dam site, one was between the dam site and the Ignatio bridge and six were found between Ignatio and Cowboy Canyon.

5.4.4.6 Waterfowl Eleven species of waterfowl were recorded on the waterfowl survey, with a mean abundance of 5.4 individuals per river mile (Table 5.4-18). The most abundant species were Canada goose (Branta canadensis)(2.8 ind/river mile), green-winged teal (Anas crecca)(1.0 ind/river mile), and mallard (Anas platyrhynchos)(0.7 ind/river mile). The other species -- in order of abundance: gadwall (Anas strepera); widgeon (Anas americana); lesser scaup (Arythya affinis); northern shoveler (Anas clypeata); blue-winged teal (Anas discors); red-breasted merganser (Mergus serrator); common merganser (M. merganser); cinnamon teal (Anas cyanoptera) -- ranged from 0.23 to 0.05 ind/river mile (see Table 5.4-13).

A two-way Analysis of Variance showed that numbers of Canada geese were not significantly different among survey days ($F_{2,38}$=2.07, p=0.14) but they

Table 5.4-18. Waterfowl abundance (individuals/river mi) along the White River from Cowboy Canyon to Asphalt Wash during 7-9 April 1982.

Species	Cowboy Canyon to Hell's Hole	Hell's Hole to Ignatio	Ignatio to Dam Site	Dam Site to Asphalt	Total Survey
Canada Goose*	2.1	3.5	3.3	2.1	2.8
Green-winged Teal	1.0	1.2	0.6	1.0	1.0
Mallard	0.2	1.5	0.4	0.7	0.7
All Waterfowl	3.7	8.5	4.8	4.8	5.4

*significantly different (p 0.05) among river miles (see Text).

did differ among river miles ($F_{19,38}$=2.40, $p<0.01$). Mile 12, approximately halfway between Ignatio and the proposed dam site, had higher goose densities than all other mile segments of the surveyed stretch of river (Fig. 5.4-24). The rest of the river showed no consistent pattern of goose density over the three days surveyed. There is no obvious reason why mile 12 should be more attractive to Canada geese than other sections of the river. Future surveys should clarify this point. Overall waterfowl distribution is shown in Fig. 5.4-25.

Dividing the river survey into four segments (Table 5.4-18) showed some areas of waterfowl concentration. The section of river from Hell's Hole Canyon to Ignatio (mile 4 to mile 7) had the highest concentration of waterfowl (8.5 ind/river mile) whereas the section from Cowboy Canyon to Hell's Hole Canyon (mile 0 to mile 4) had the lowest concentration (3.7 ind/river mile). The sections from Ignatio to the proposed dam site and from the dam site to Asphalt Wash had intermediate abundances (4.8 ind/river mile, for both sections).

5.4.5 Mammals Discussion of mammals is divided into three sections: rodents (data from trapping grids), desert cottontails (data from flushing transects), and mule deer (data from opportunistic sightings and flushing transects).

5.4.5.1 Rodents Between 1981 and 1982 mean rodent density increased by 9%, richness decreased by 4%, diversity increased by 25%, evenness increased by 29%, and biomass increased by 48%. In the following discussion, 1982 values for these parameters obtained from each trapping grid are compared to 95% confidence limits established during 1975-1981 on the primary trapping grids (G-1, J-1, S-1, R-1).

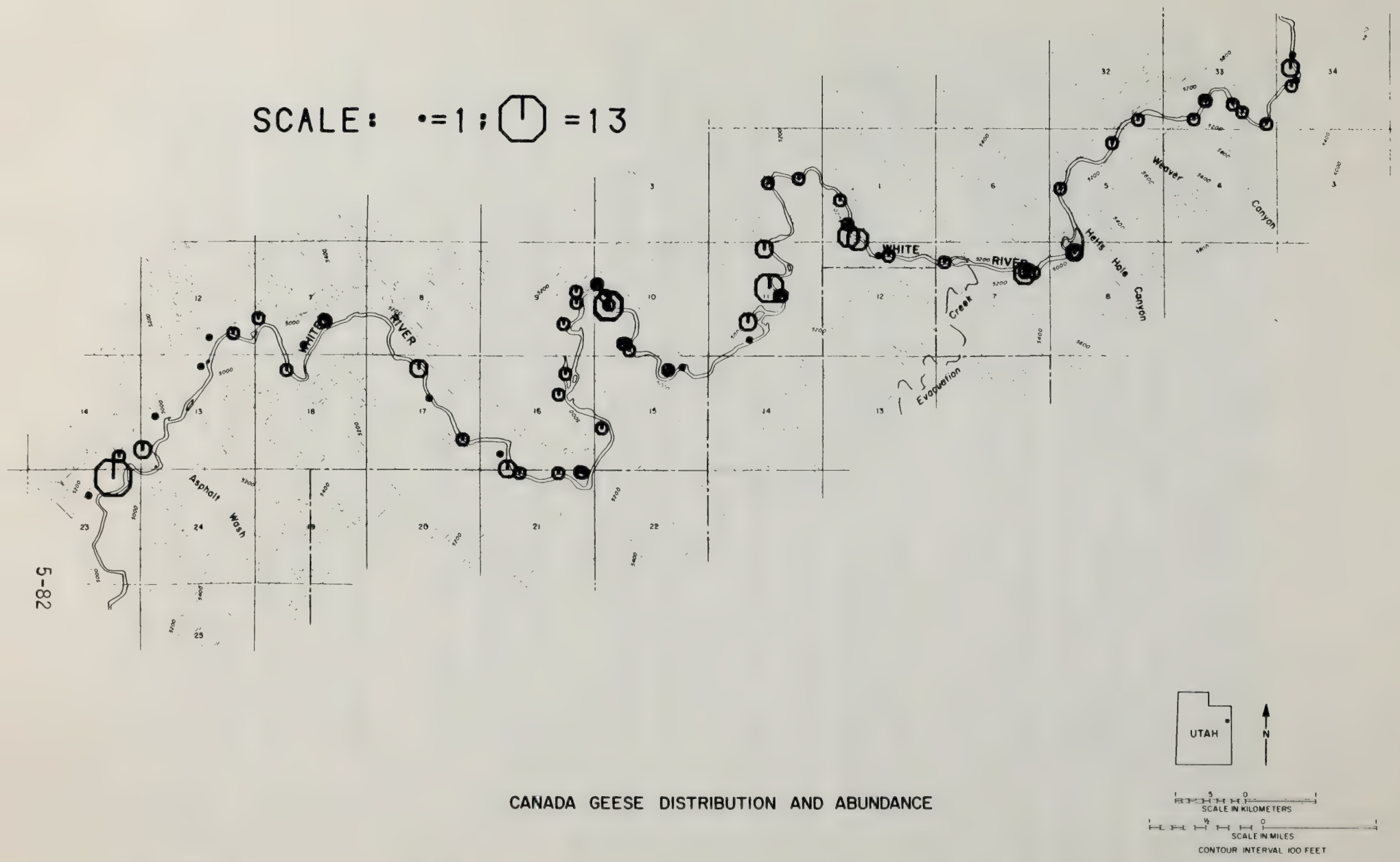


Fig. 5.4-24. Distribution and abundance of the Canada Goose along the White River from Cowboy Canyon to Asphalt Wash from 7-9 April 1982.

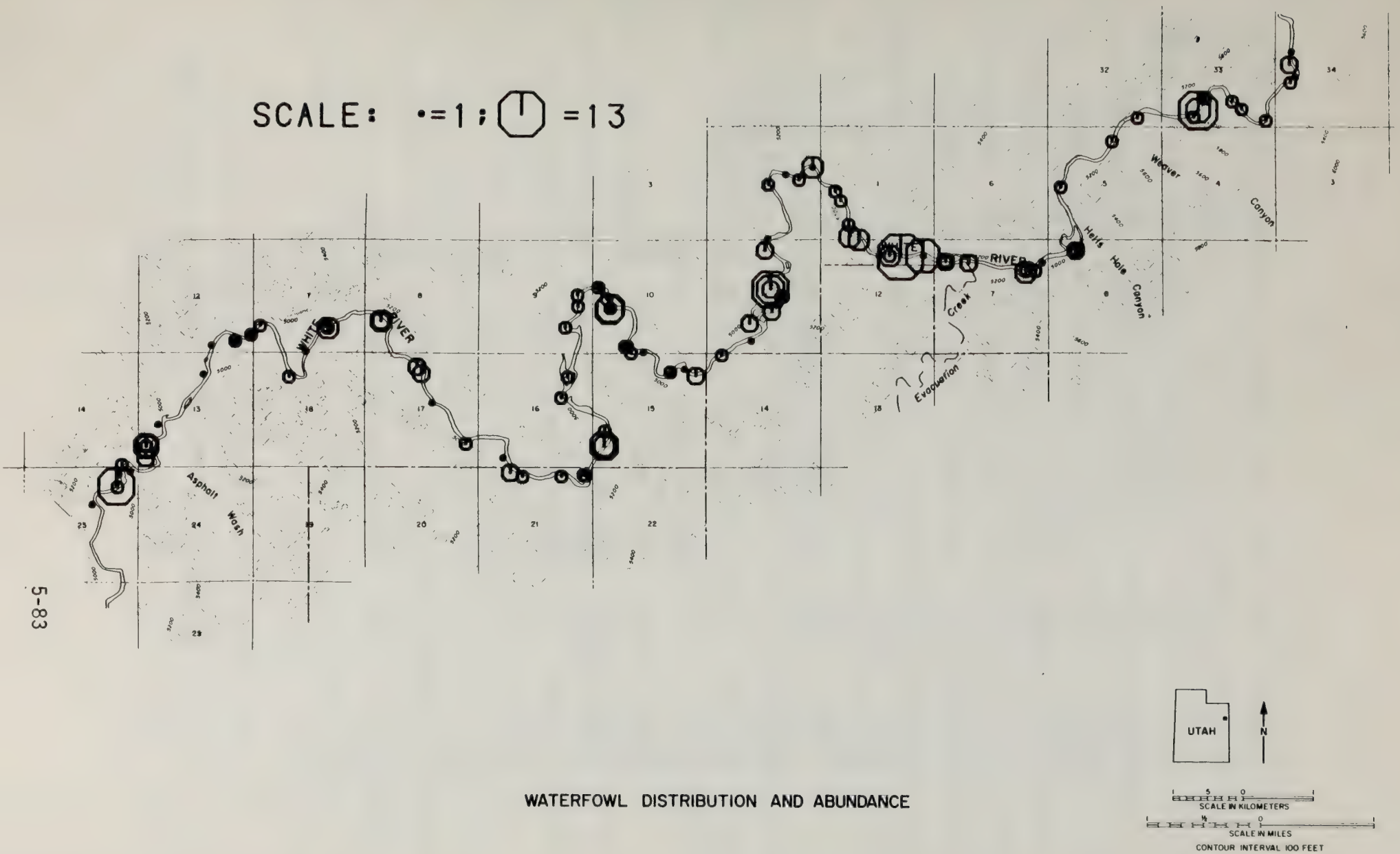


Fig. 5.4-25. Distribution and abundance of all waterfowl along the White River from Cowboy Canyon to Asphalt Wash from 7-9 April 1982.

In Greasewood during 1982, rodent diversity and evenness occurred above the 95% confidence interval (CI)(Fig. 5.4-26). This increase in diversity and evenness at G-1 and G-3 were due to a significant decrease in Ord's kangaroo rat (Dipodomys ordii) density, historically the dominant species in Greasewood. However, at Greasewood site G-2, which is located in a wide basin in Southam Canyon (whereas G-1 and G-3 are located in narrower valleys) no species was dominant (yielding higher evenness and diversity). The slight increase in density of two large species, white-tailed antelope squirrels (Ammospermophilus leucurus) and desert woodrats (Neotoma lepida) resulted in the 2-fold increase in biomass at G-2.

In Shadscale, the invasion of canyon (Peromyscus crinitus) and pinon mice (Peromyscus truei) at site S-4 resulted in richness and diversity indices occuring above the CI (Fig. 5.4-27). The decrease in density at both S-1 and S-4 were due again to a decrease in kangaroo rat densities.

In Juniper, 4 species, canyon and pinon mice, and desert and bushy-tailed woodrats (Neotoma cinerea), increased in density causing an increase in total density and biomass (Fig. 5.4-28). Kangaroo rat density decreased on both J-1 and J-5. Richness, diversity, and evenness at J-1 remained above the CI as they were in 1981. In 1982 the antelope squirrel, which had been extinct in Shadscale and Juniper since the 1977 drought, recolonized both habitats and began approaching densities seen in 1975 and 1976. The presence of this squirrel, the two mice and two woodrats caused the high richness and diversity at J-1.

Whereas 1982 rodent density and biomass in Greasewood, Shadscale and Juniper fall within the CI, rodent density and biomass in Riparian were well above the CI (Fig. 5.4-29). Nevertheless, rodent richness, diversity, and

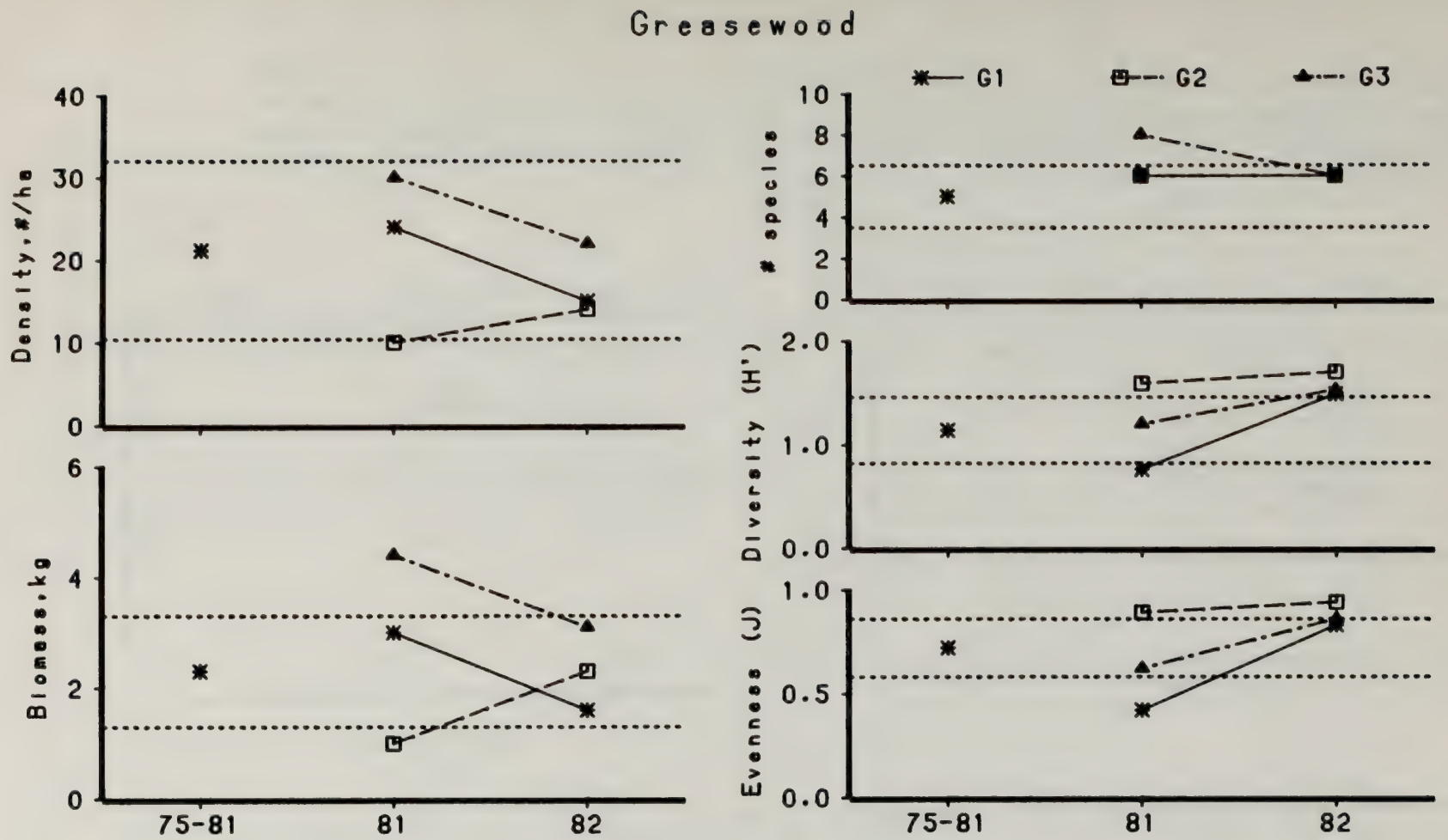


Fig. 5.4-26. Density (ind/ha), biomass (kg/ha), species richness, diversity (H'), and evenness (J') of rodents in Greasewood in August 1981 and 1982, compared to means in August during the baseline period (1975-1981). 95% confidence limits of the baseline data are horizontal broken lines.

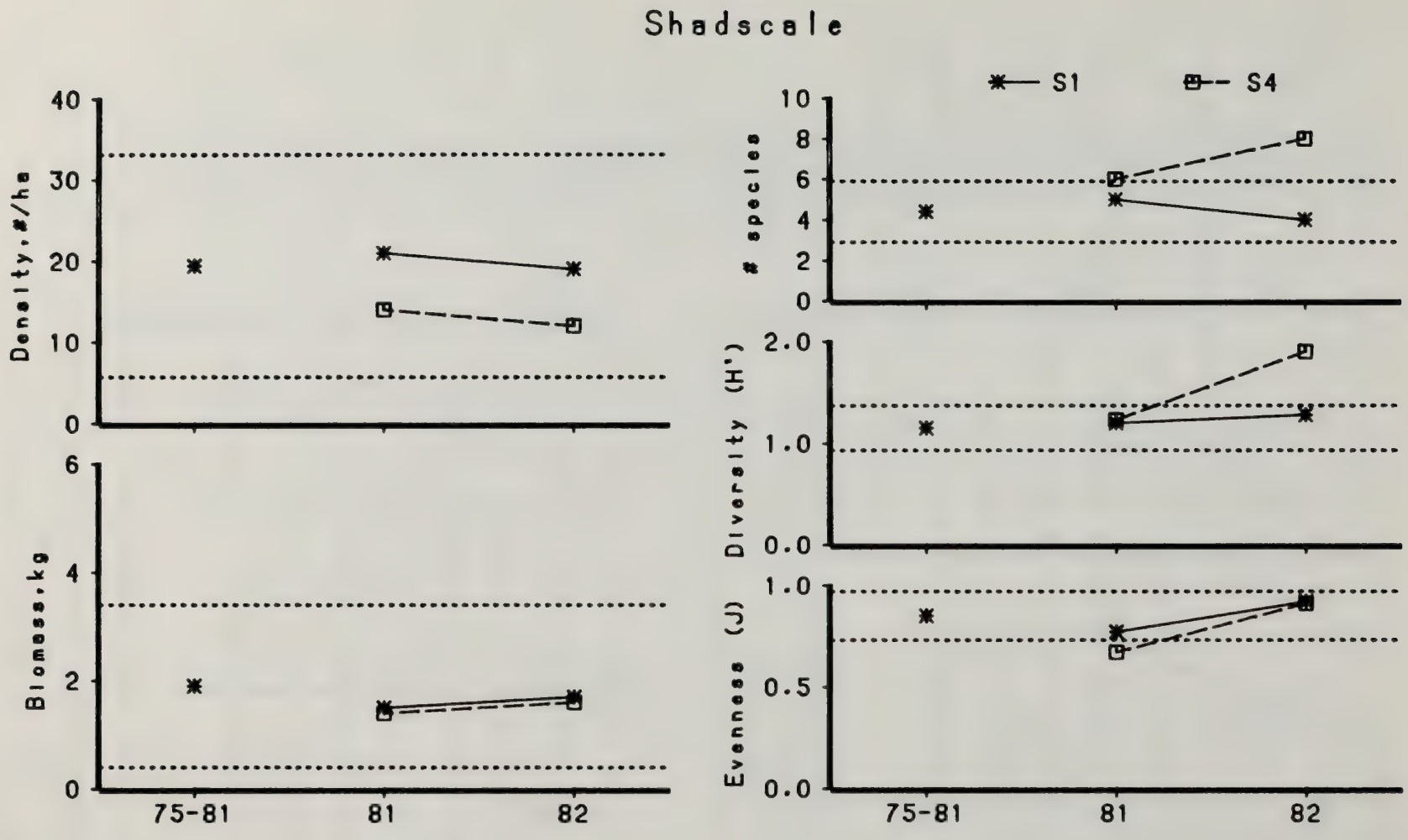


Fig. 5.4-27. Density (ind/ha), biomass (kg/ha), species richness, diversity (H'), and evenness (J') of rodents in Shadscale in August 1981 and 1982, compared to means in August during the baseline period (1975-1981). 95% confidence limits of the baseline data are horizontal broken lines.

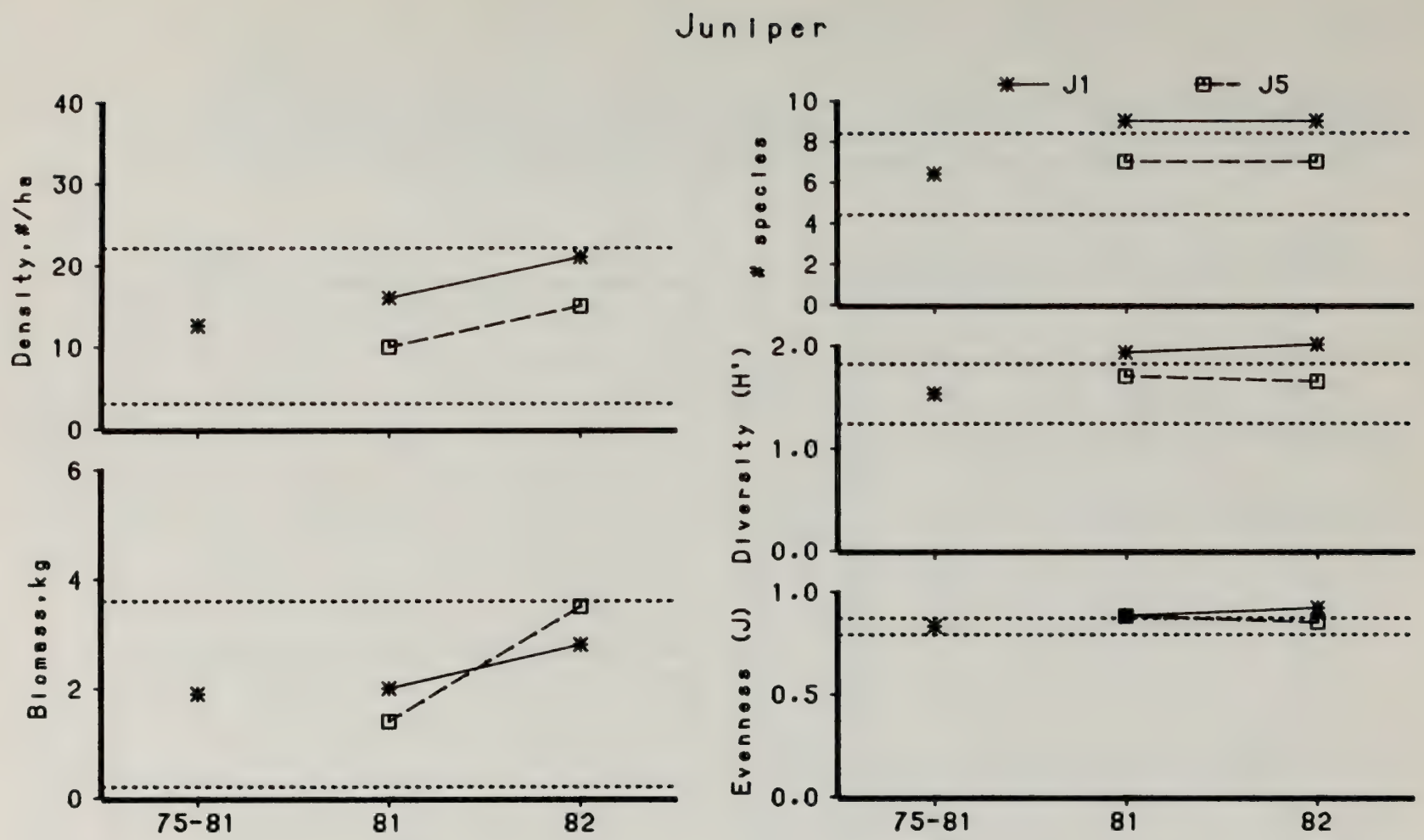


Fig. 5.4-28. Density (ind/ha), biomass (kg/ha), species richness, diversity (H'), and evenness (J') of rodents in Juniper in August 1981 and 1982, compared to means in August during the baseline period (1975-1981). 95% confidence limits of the baseline data are horizontal broken lines.

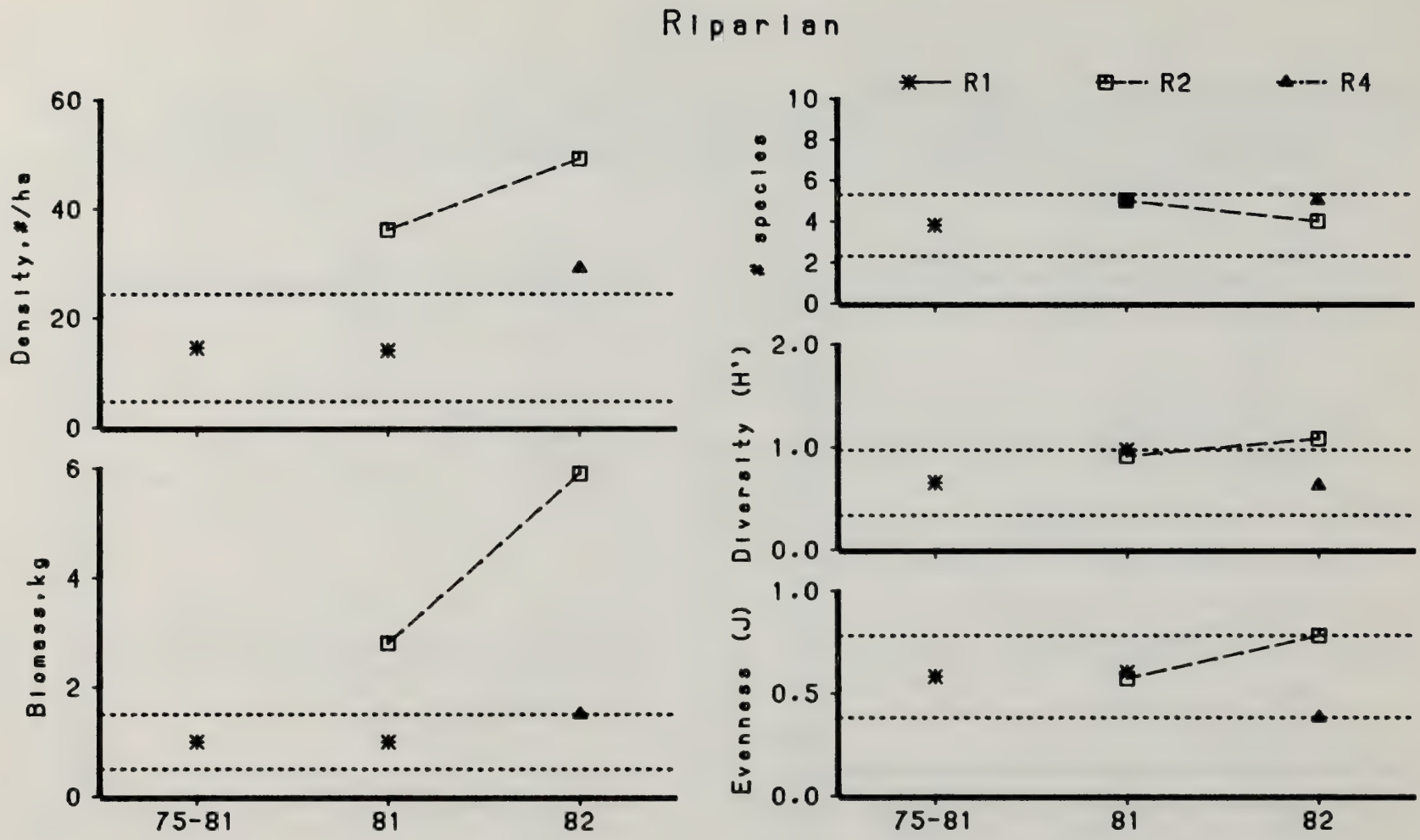


Fig. 5.4-29. Density (ind/ha), biomass (kg/ha), species richness, diversity (H'), and evenness (J') of rodents in Riparian in August 1981 and 1982, compared to means in August during the baseline period (1975-1981). 95% confidence limits of the baseline data are horizontal broken lines.

evenness at sites R-2 and R-4 were within or near the CI for R-1. The large differences in density and biomass between sites R-2 and R-1 were apparently due to two factors. First, the R-1 grid contains cottonwood stands plus grass and forbs near the river bank. At site R-2 the grid includes the above plus a substantial amount of rabbitbrush and greasewood. Although species compositions in R-1 and R-2 were very similar in 1981 (91% similarity), R-2 supported four times as many Ord's kangaroo rats, three times as many deer mice (Peromyscus maniculatus) and two times as many western harvest mice (Reithrodontomys megalotis) as R-1. Second, at R-2, montane voles (Microtus montanus) which occurred at a density of 0.4 ind/ha in October 1981 increased to 22 ind/ha in August 1982. The increase in rodent density at R-2 between 1981 and 1982 occurred despite a substantial flash flood which deposited 5 to 50 cm of sediment over the entire R-2 grid two days prior to trapping. Apparently, this type of disturbance does not affect rodent populations.

None of the changes in rodent populations could be ascribed to road and plant site construction, or increased human activity on Tracts Ua and Ub. The decrease in density of Ord's kangaroo rat occurred at all sampling sites. Antelope squirrels, the two woodrats, and canyon and pinon mice all increased in density where they were found. These changes could be attributed to heavy precipitation in fall 1981 which favored abundant germination of seeds and marked growth of annual and perennial plants. Abundant germination of seeds may have decreased seed availability causing the decrease in kangaroo rats. The high production of above-plant matter may have led to the increase in herbivorous and omnivorous rodents.

Since the changes in rodent populations did not appear to be due to mine development and road construction, which occurred at a low level, results from

1982 are considered baseline. Thus the 1982 data for G-1, S-1, and J-1 can be used to calculate the mean and 95% confidence intervals (Table 5.4-19) for detecting future development-related impact or enhancement.

Small mammals belong to three trophic groups: granivores (Ord's kangaroo rat and Apache pocket mouse [Perognathus apache]), herbivores (desert woodrat, bushy-tailed woodrat and montane vole), and omnivores (white-tailed antelope squirrel, least chipmunk [Eutamias minimus]), deer mouse, canyon mouse, pinon mouse, brush mouse [Peromyscus boylei]), western harvest mouse, and golden-mantled ground squirrel [Spermophilus lateralis]). Changes in these trophic groups from 1975 through 1981 are illustrated in Fig. 5.4-30 for each sampling site.

The granivore trophic group is strongly represented in Greasewood and Shadscale habitats but poorly represented in Juniper and Riparian. On both G-1 and S-1 trapping grids, granivores maintained fairly stable population levels from 1975 through 1979. But in 1980 granivore populations increased dramatically and remained high in 1981. These increases were due to increases in Ord's kangaroo rat density. In 1982, granivore population on G-1 returned to the 1975-1979 level but on S-1 they remained high. Too few data are available to determine whether similar changes occurred on G-2, G-3, and S-4 (Fig. 5.4-30). Causes of changes are unclear. However, these desert adapted rodents do not appear to respond to very moist conditions (1975) or extreme droughts (1977). Presumably the 1980-1981 increase was caused by increases in seed resources.

Table 5.4-19. Population parameters (± 95% confidence interval) for rodents in four habitat types on Utah Oil Shale Tracts, Ua and Ub.

	Habitats			
Population Parameters	Greasewood*	Shadscale*	Juniper*	Riparian**
Density, Ind/ha	20.5±9.2	19.4±11.5	13.7±8.4	14.5±9.8
Biomass, Kg/ha	2.2±0.8	1.8±1.1	2.0±1.4	1.0±0.5
Richness, No. spp.	5.1±1.3	4.4±1.3	6.8±1.9	3.8±1.5
Diversity, H'	1.19±0.27	1.16±0.18	1.59±0.28	0.65±0.32
Evenness, J'	0.74±0.12	0.86±0.10	0.84±0.04	0.58±0.20

* Data from G-1, S-1, and J-1, 1975 to 1982
** Data from R-1, 1975 to 1981

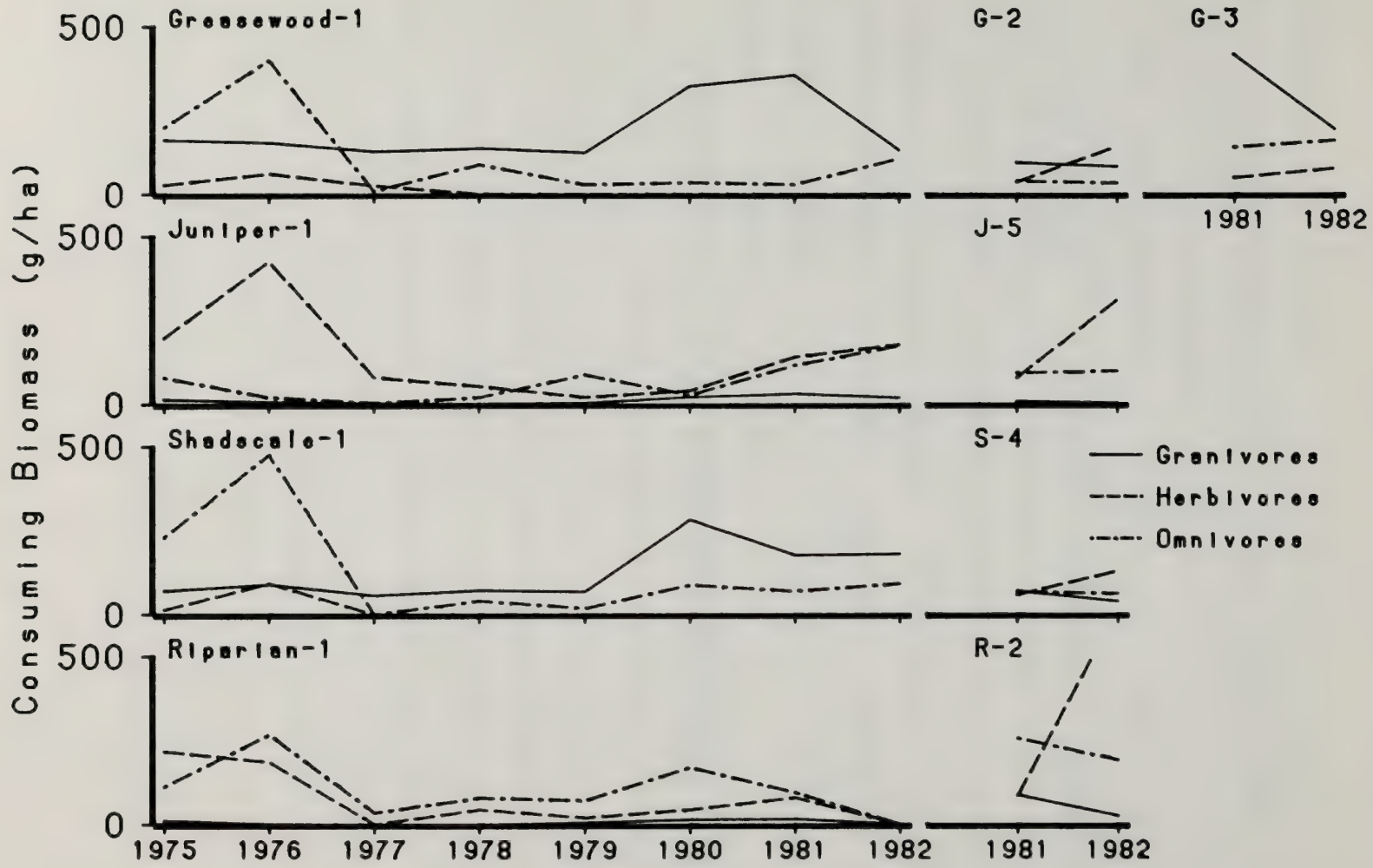


Fig. 5.4-30. Consuming biomass (g/ha) of 3 rodent trophic groups on 4 trapping grids during August from 1975 through 1982 and on 5 trapping grids during August in 1981 and 1982.

Herbivores are well represented on J-1 and R-1 but uncommon on G-1 and S-1. Populations at all sites were high during 1975 and 1976, wet years when forbs and grasses were abundant, but following the 1977-1978 drought, herbivore populations decreased markedly on J-1 and R-1 and became extinct on G-1 and S-1. Herbivore populations have increased on J-1 and R-1 since 1981. However on G-1 and S-1 herbivores still have not recolonized in measurable densities although healthy populations have been recorded on G-2, G-3 and S-4 since 1981 (Fig. 5.4-30). Changes in herbivore populations in Riparian seem to be dependent on annual-plant biomass ($r=0.67$, $df=5, \alpha 0.05$, $p<0.10$) but in Juniper the correlation is not significant ($r=-0.30$, $df=6$).

Omnivores are well represented in all habitats. Populations were high in 1975 and 1976 but decreased drastically during the 1977 drought. In 1977, omnivores were absent on S-1 and nearly so on J-1. Omnivores recovered quickly from the drought and since 1978 populations have increased, although in G-1 and S-1 populations have not yet reached pre-drought levels.

5.4.5.2 Desert Cottontails Three-way Analysis of Variance (ANOVA) showed significant differences among years ($F_{7,78}=70.23$, $p<0.001$), seasons ($F_{4,78}=24.50$, $p<0.001$), and habitat types ($F_{3,78}=13.90$, $p<0.001$) in density of desert cottontails (*Sylvilagus auduboni*) during 1975 through 1982. Changes over years indicate what appears to be a cycle of population fluctuations with a periodicity of approximately six years (Fig. 5.4-31). Least Significant Difference test (LSD)(Steel and Torrie 1960) showed that most differences between pairs of years were significant with the exception that the years of low density, 1975, 1979, 1980 and 1981, were generally not significantly different from each other. Populations in 1976 were higher than in any other year and those in 1977 were higher than in any other year except 1976. Popu-

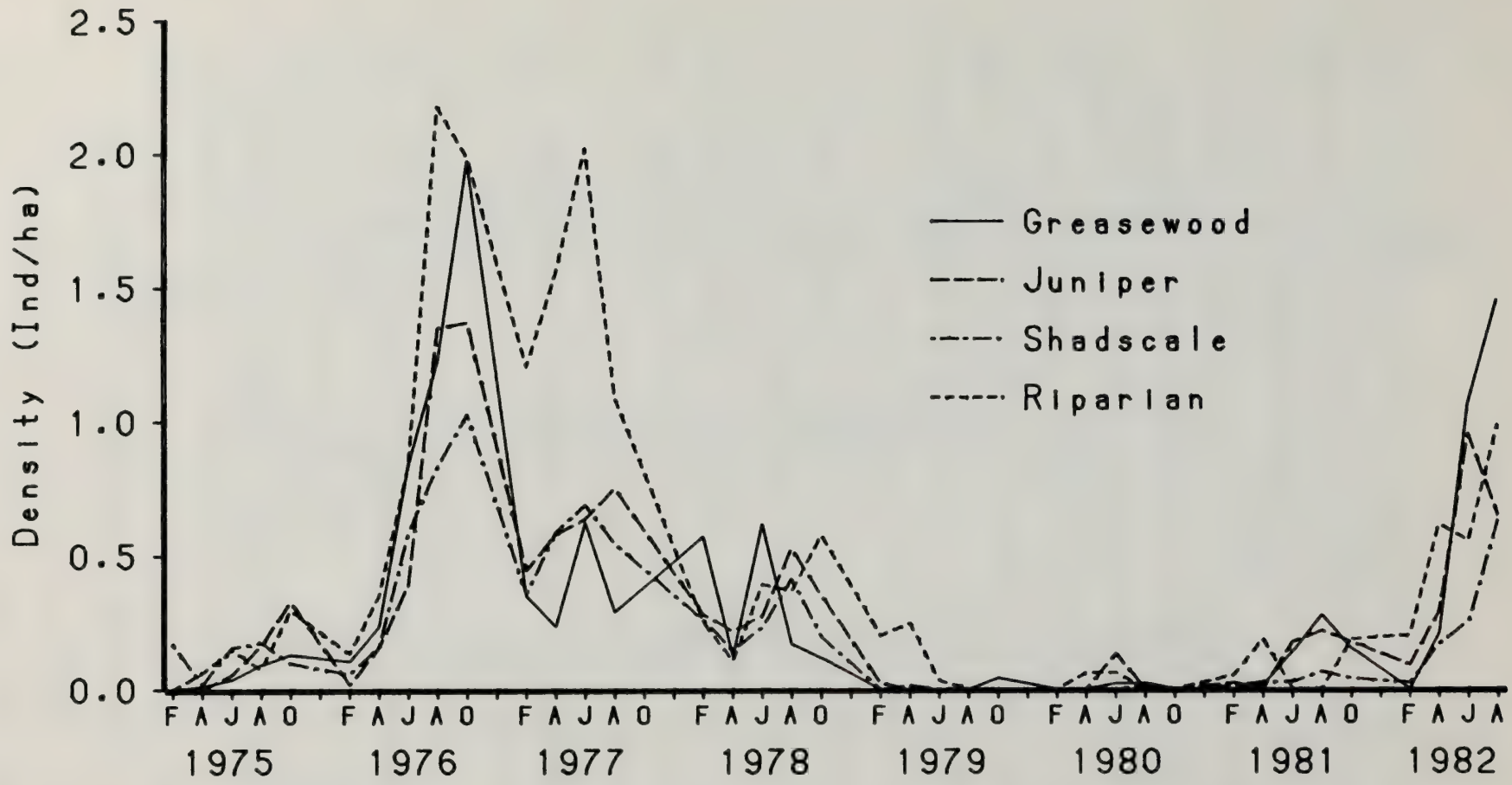


Fig. 5.4-31. Density (ind/ha) of desert cottontails in 4 habitats, bimonthly from 1975 through 1982.

lation cycles have been reported for other lagomorphs: black-tailed jackrabbit (Lepus californicus, Gross et al. 1974) and snowshoe hare (Lepus americanus, Odum 1971, p. 191). Both these species cycle with periods of approximately seven years. To our knowledge no population cycle for desert cottontails has been reported. The fact that cottontail populations cycle limits their utility in terms of detecting impacts. It has been thought that population cycles of animals are related to changes in forage availability, which in turn is affected by overgrazing by the population. If this were true for desert cottontails, an impact from industrial development might be reflected in a deviation from the pattern of cycle. However, in no case has cause of population cycles been positively determined. Thus, interpretation of changes in desert cottontail populations is difficult.

Cottontail density increased in spring during the reproductive season and decreased during late fall and winter due presumably to mortality. Density in February and April was not significantly different. Density increased significantly (LSD) between April and June. August populations were not significantly different from June's, however October populations were higher than those in June. Between October and February, populations declined significantly.

Differences among vegetation types in cottontail density were also significant. Density in Riparian was higher than in all three upland habitats. This is presumably due to the greater availability of herbaceous forage in Riparian habitat. Density was not significantly different between any of the upland habitats.

5.4.5.3 Mule Deer Mule deer (Odocoileus hemionus) are uncommon on Tracts Ua and Ub. Sixteen mule deer were recorded along 152 kilometers of

transect in 1982 (Table 5.4-20). Most deer were seen in April and June (0.18 and 0.24 deer/km, respectively), and these were seen only in Juniper and Riparian habitats.

One hundred and twenty-two deer sightings were made on or near the Tracts in 1982, including observations both on and off transects (Table 5.4-21). Deer were present during all four months sampled but were most common in April. All deer were seen in either Juniper woodland, Riparian woodland, or dry, sparsely vegetated canyons near the Riparian habitats. The distribution of these sightings in each month is illustrated in Figs. 5.4-32 through 5.4-35.

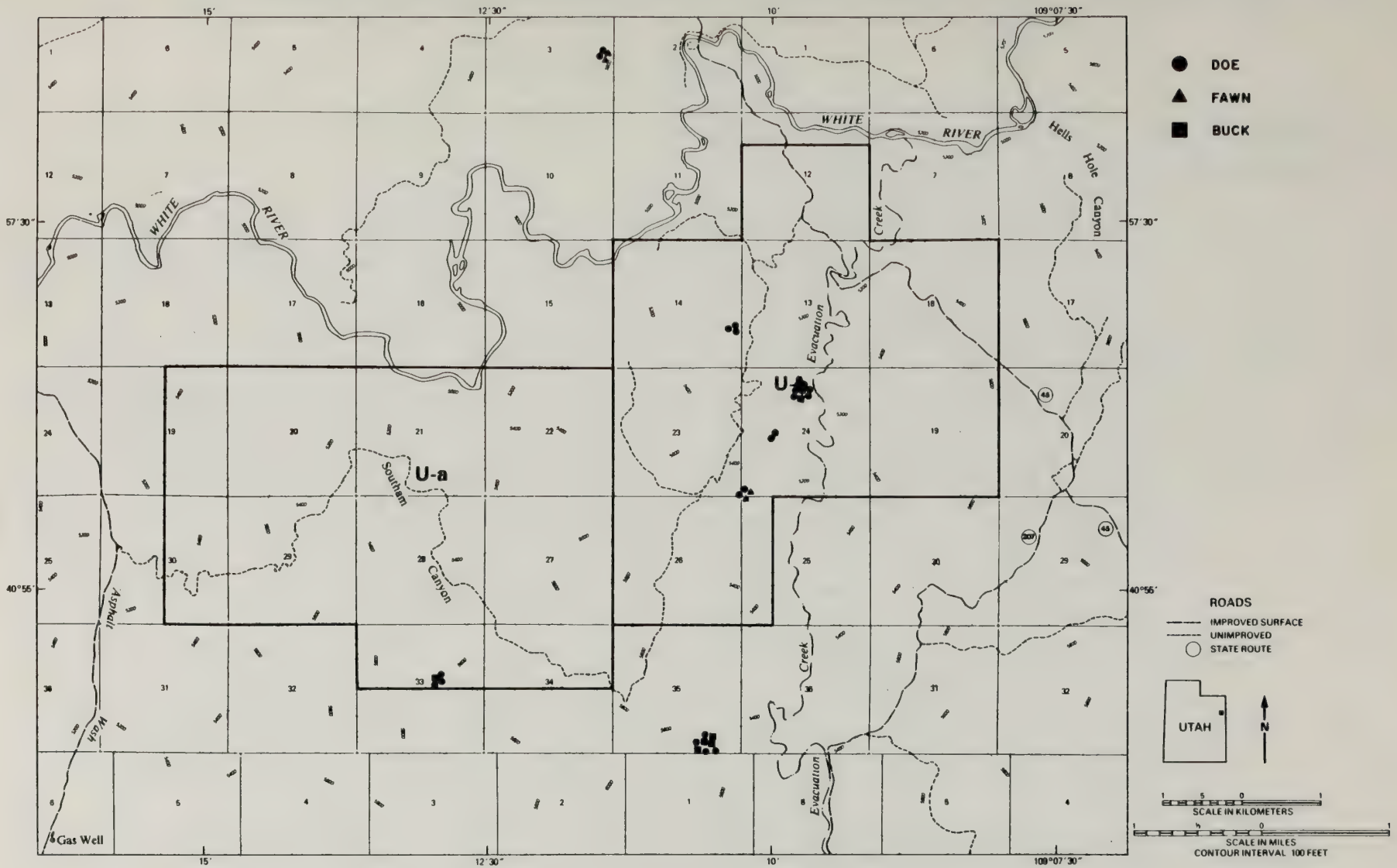
Herd sizes were largest in February and April (4.9 and 5.3, respectively; Table 5.4-21). In early summer these herds broke up, and during June and August groups of one to three deer, usually a doe with one or two fawns, were seen. The occurrence of fawns indicates that some reproduction may occur on Tracts Ua and Ub, but the most important fawning grounds in the area are in the Book Cliffs to the south. Insufficient data are available to calculate reliable buck-doe and fawn-doe ratios.

Table 5.4-20. Abundance of mule deer seen along flushing transects in 1982.

Transect	Month				Total kilometers censused	Deer/km
	February	April	June	August		
G-1	0	0	0	0	21	0
G-2	0	-	0	0	15	0
G-3	0	-	0	0	15	0
J-1	0	3	5	1	18	0.50
J-5	0	-	1	0	15	0.07
R-2	0	0	3	0	18	0.17
R-4	0	0	2	1	17	0.18
S-1	0	0	0	0	18	0
S-4	0	-	0	0	15	0
Total kilometers censused	45	17	45	45		
Deer/km	0	0.18	0.24	0.04		

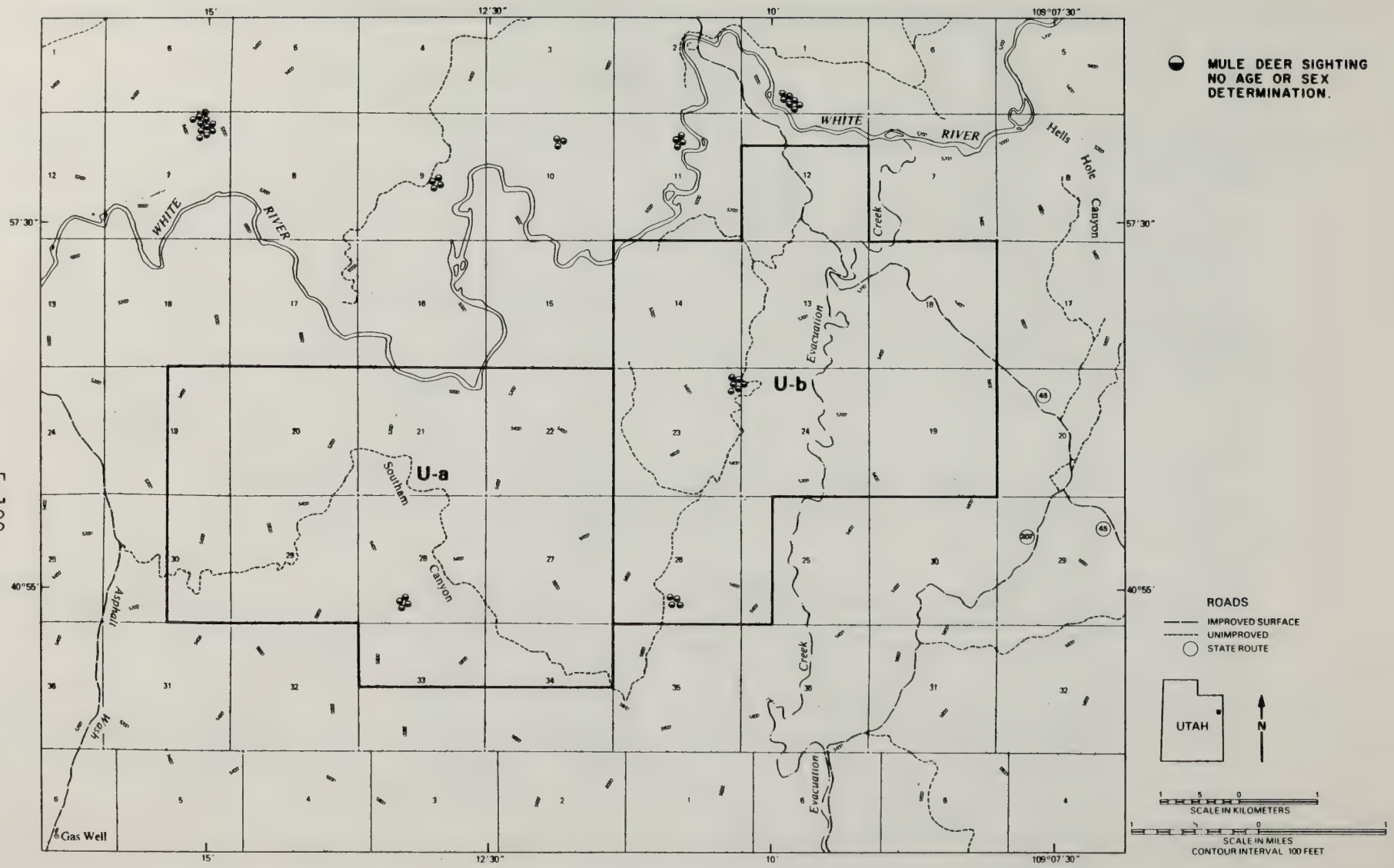
Table 5.4-21. A summary of all deer seen (both on and off flushing transects) on or near Utah Oil Shale tracts, Ua and Ub in 1982.

	Month			
	February	April	June	August
Number of sightings	7	8	11	11
Number of deer	34	42	19	27
Bucks	6	0	6	1
Does	24	0	7	11
Fawns	4	0	1	12
Unidentified	0	42	5	3
Mean herd size	4.9	5.3	1.7	2.5
Habitats	Juniper	Juniper; Riparian and adjacent canyons	Juniper; Riparian and adjacent canyons	Juniper; Riparian and adjacent canyons



MULE DEER SURVEY-FEBRUARY 1982

Fig. 5.4-32. Mule deer sightings on and near the Federal Oil Shale Prototype tracts, Ua and Ub, in February 1982. See legend for symbol definitions.



MULE DEER SURVEY - APRIL 1982

Fig. 5.4-33. Mule deer sightings on and near the Federal Oil Shale Prototype tracts, Ua and Ub, in April 1982. See legend for symbol definitions.

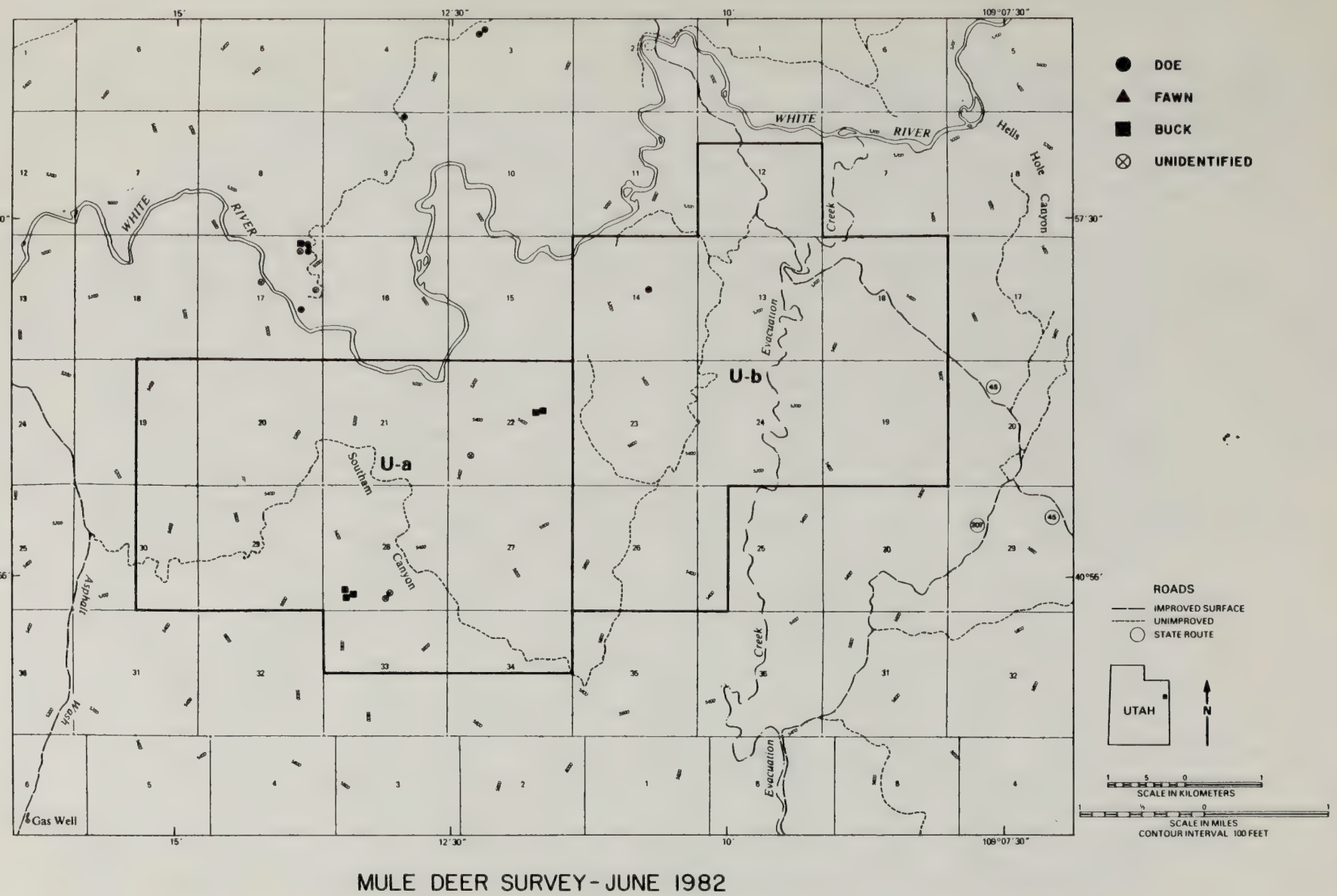
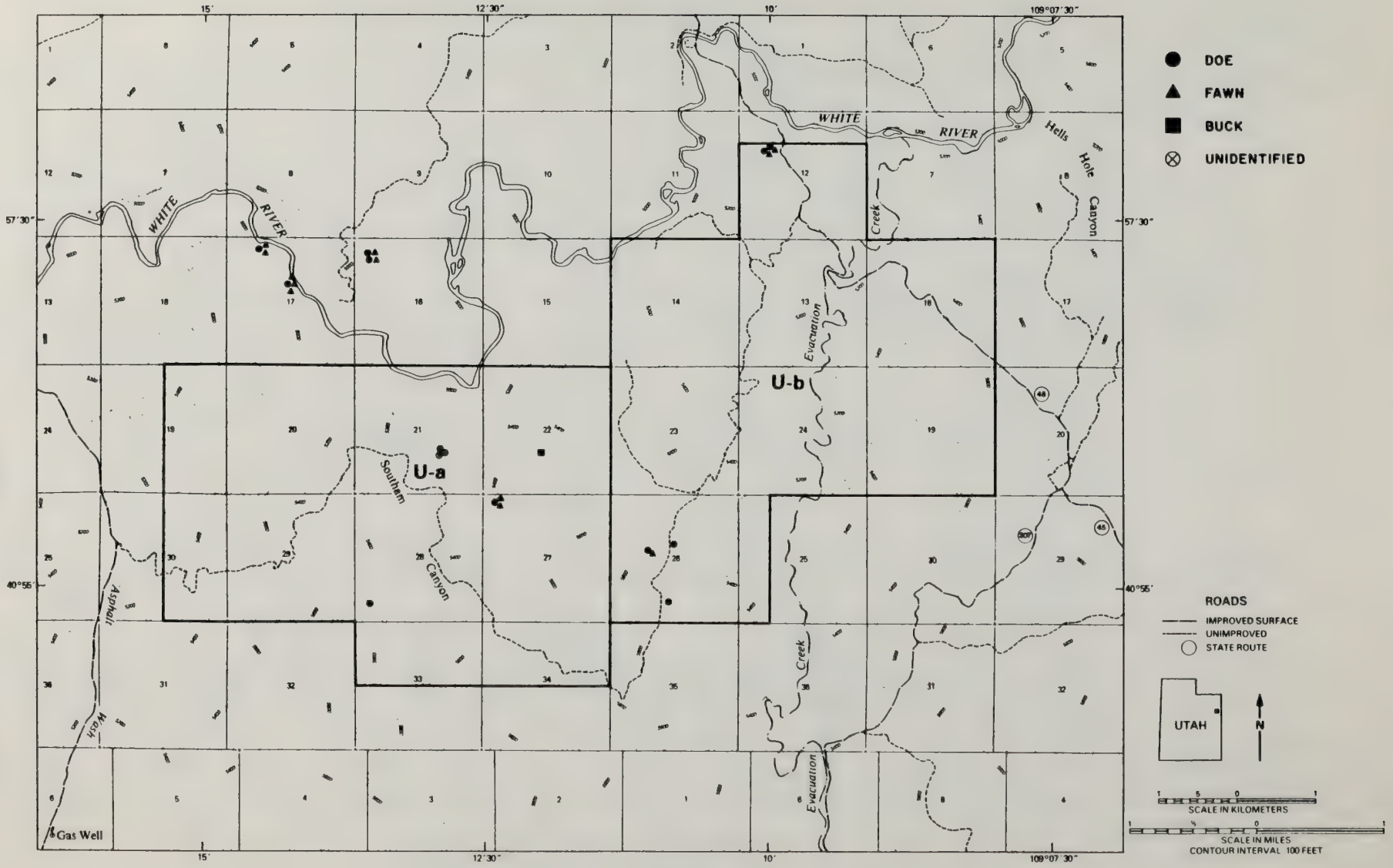


Fig. 5.4-34. Mule deer sightings on and near the Federal Oil Shale Prototype tracts, Ua and Ub, in June 1982. See legend for symbol definitions.



MULE DEER SURVEY - AUGUST 1982

Fig. 5.4-35. Mule deer sightings on and near the Federal Oil Shale Prototype tracts, Ua and Ub, in August 1982. See legend for symbol definitions.

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WATER RESOURCES

6.0 WATER RESOURCES

6.1 INTRODUCTION

The water resources monitoring program for the White River Shale Project (WRSP) was initiated in August 1974, and has continued without interruption to the present time. This section of the Progress Report discusses work performed during the period October 1, 1981 through September 30, 1982, which is referred to as the 1982 water year. This program element has been conducted by VTN Consolidated, Inc. of Irvine, California.

The 1982 water year monitoring program involved monitoring of surface water, bedrock aquifers, alluvial aquifers, precipitation and evaporation on and near the tracts. It also included a formal description of the Quality Assurance and Quality Control (QA/QC) program and the documentation of efforts to meet the QA/QC program objectives as described in the Environmental Monitoring Manual (WRSOC June 1982), hereafter referred as the EMM, and a technical memorandum (VTN 1982) for this project.

During the past water year, field data collection was performed by an employee of WRSOC, under the direction of VTN. VTN was responsible for data reduction and analysis and the preparation of reports for the water resources program.

The United States Geological Survey (USGS) has been conducting its own water resources data collection program in the southeastern Uinta basin throughout the project life. During the 1982 water year, the USGS efforts involved collection of streamflow and water quality data in the immediate vicinity of the tracts. The WRSP surface water monitoring program was designed to be used in conjunction with portions of the USGS program to meet

monitoring objectives for the project. All USGS data presented in this report are preliminary and subject to revision, since they were "provisional" at the time of report preparation.

6.2 SUMMARY

Precipitation was well above average at the WRSP precipitation gauges during the 1982 water year. Annual precipitation on or near the tracts ranged from 13.80 inches at the plant site to 15.73 inches at the mouth of Southam Canyon. The above normal precipitation was primarily the result of several large scale fall and summer storms. Pan evaporation during the freeze-free period of May through September was similar to previous years.

Annual runoff for the White River monitoring stations 6395 (near Colorado State line) and 6700 (below Asphalt Wash) was somewhat above normal. Several relatively large regional thunderstorm runoff events occurred during October 1981 and July through September 1982. Available suspended sediment and water quality records did not indicate that there were any major differences between the upstream station (6395) and downstream station (6700) during 1982, or between 1982 and previous years.

Annual runoff and the maximum instantaneous discharge for Evacuation Creek near the mouth (station 6430) during 1982 were the highest values out of eight years of record. Both were due to the numerous and wide-spread summer thunderstorms that occurred in the higher elevations of this watershed (off-tract). Suspended sediment and water quality data collected at station 6430 were generally similar to previous years. This was expected since no significant project-related disturbance has occurred to date in this watershed.

Annual runoff and the maximum instantaneous discharge for Southam Canyon Wash at mouth (station 6610) during 1982 were the second and third highest values, respectively, out of eight years of record. Station 6602 near the mouth of Plant Site Wash recorded a 1982 annual runoff of 7.9 acre-feet and a maximum instantaneous discharge of 43 cfs. The 1982 streamflow record for station 6625 near the mouth of Asphalt Wash is not available at the present time.

Suspended sediment and water quality data for Southam Canyon Wash in 1982 were similar to data from previous years. This was expected because no significant project-related disturbance has occurred to date in this watershed.

Since there are no suspended sediment and water quality records for Plant Site Wash from previous years, the 1982 data were compared to those from Southam Canyon Wash. This comparison indicated that suspended sediment concentrations for Plant Site Wash were greater than those for Southam Canyon at relatively small flows (< 5 cfs), but were similar during larger flows. This was attributed to the increased transport of fine-grained material (silt and clay) from disturbed areas within the Plant Site Wash drainage. The expected increase during larger flows was probably masked out because the percentage of fine- grained material in suspended sediment typically decreases as flow increases. The increased transport of suspended sediment from Plant Site Wash did not have a noticeable effect on the suspended sediment characteristics of the White River. There were also notable differences for several water quality constituents between samples collected on September 29, 1982 at stations 6602 and 6610. The concentrations of the nutrients (nitrogen and phosphorus compounds) in the suspended phase and iron and nickel in the dissolved phase were considerably greater for runoff from Plant Site Wash than for runoff from Southam Canyon Wash. The cause(s) for these differences are not fully understood at the present time.

The USGS was unable to collect any suspended sediment or water quality samples for Asphalt Wash (station 6625) during 1982.

Static water level monitoring of Birds Nest Zone wells during 1982 indicated that there were notable differences from previous years. Water levels at well P-1 began in June to exhibit a series of rapid fluctuations that lasted through August. These fluctuations were uncharacteristic of this

well, since it had remained stable for several years prior to June 1982. The changes in water levels at well P-1 may have been caused by surface excavation blasting occurring near this site at the time.

Several Birds Nest Zone wells (P-2 Lower, G-5, G-15 and G-21) in the western portion of the tracts continued to exhibit slow and steady declines in water level that began in mid-1980. Two additional wells (G-10 and G-11) in the central portion of the tracts began to exhibit similar declines between 1981 and 1982. Water levels at the remaining Birds Nest Zone wells (G-8, G-8A and P-3) in the eastern and southeastern portions of the tracts were similar to previous years. The declining water levels in the Birds Nest Zone may have been caused by increased discharge from this zone to the north or northwest of the tracts. However, they are not believed to represent any significant depletion in storage of the Birds Nest Zone below the tracts.

Water levels during 1982 for wells monitoring the Upper Aquifer and the Douglas Creek Aquifer were stable and similar to previous years of record.

Monitoring results in 1982 for the three alluvial wells indicated that water level fluctuations and water quality were similar to results for 1982. A water quality sample was collected from well AG-6-1 at the mouth of Southam Canyon in May 1982 in order to define the changes in baseline water quality since the last sample was collected in September 1979.

Suspended sediment and water quality data for Southam Canyon Wash in 1982 were similar to data from previous years. This was expected because no significant project-related disturbance has occurred to date in this watershed.

Since there are no suspended sediment and water quality records for Plant Site Wash from previous years, the 1982 data were compared to those from Southam Canyon Wash. This comparison indicated that suspended sediment concentrations for Plant Site Wash were greater than those for Southam Canyon at relatively small flows (< 5 cfs), but were similar during larger flows. This was attributed to the increased transport of fine-grained material (silt and clay) from disturbed areas within the Plant Site Wash drainage. The expected increase during larger flows was probably masked out because the percentage of fine- grained material in suspended sediment typically decreases as flow increases. The increased transport of suspended sediment from Plant Site Wash did not have a noticeable effect on the suspended sediment characteristics of the White River. There were also notable differences for several water quality constituents between samples collected on September 29, 1982 at stations 6602 and 6610. The concentrations of the nutrients (nitrogen and phosphorus compounds) in the suspended phase and iron and nickel in the dissolved phase were considerably greater for runoff from Plant Site Wash than for runoff from Southam Canyon Wash. The cause(s) for these differences are not fully understood at the present time.

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6.3 PROGRAM DESCRIPTION

The water resources program has been designed to document and assess potential project-related impacts on the hydrologic environment. To fulfill this objective, the 1982 program continued to collect baseline (pre-construction) data for tract watersheds and ground water systems which potentially will be, but have not yet been, affected by project development activities. Some construction activities were initiated during the 1982 water year, particularly within the Plant Site Wash watershed. Monitoring at station locations that could potentially be impacted by current construction activities was designed to allow identification of a project-related impact through comparison to concurrent data collected at control stations and/or previously collected baseline data.

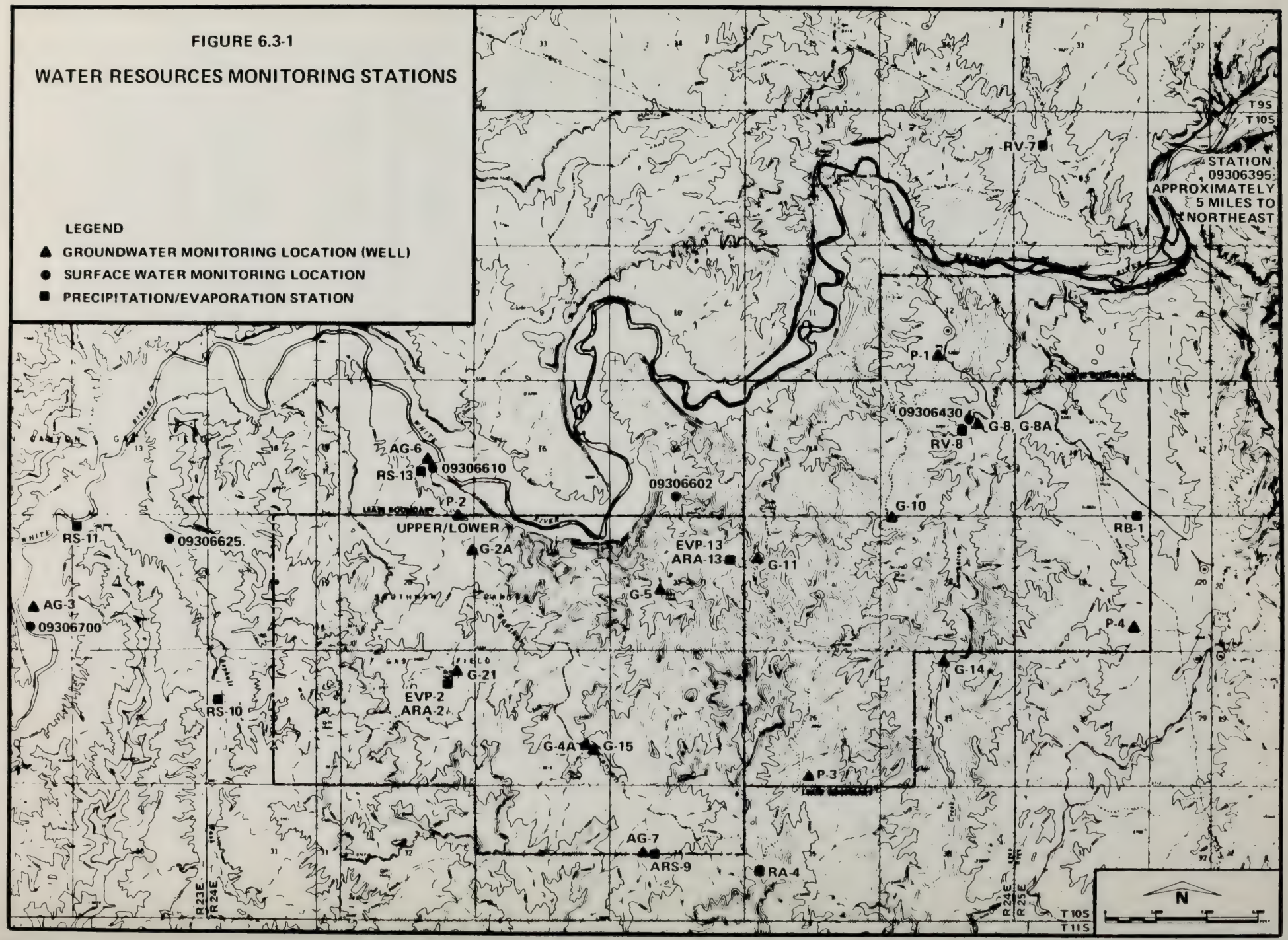
The water resources monitoring stations have been located so as to detect: (1) unplanned point surface discharges, such as accidental spills or leaks from retention dams or impoundments; (2) non-point surface discharges, such as runoff from areas of road construction and other project activities; and (3) point and non-point source discharges into local ground water systems. The monitoring station locations are shown in Figure 6.3-1.

This report uses the USGS system of nomenclature for station numbers and names, as opposed to previous reports where dual nomenclature systems were used. In addition, only the last four digits of the USGS station numbers are used in the text.

6.3.1 Surface Water The surface water gauging stations and water quality sampling sites monitor the quantity and quality of surface water on or near the tracts. Stations adjacent to, and upstream of the project site serve as control stations. These sites are unaffected by WRSOC activities and monitor natural or non-project related hydrologic fluctuations. Stations

FIGURE 6.3-1

WATER RESOURCES MONITORING STATIONS



situated downstream of the tracts are designated as treatment stations. These sites presently, or will in the future, monitor the potential effects of project activities in each drainage basin of concern.

The 1982 surface water monitoring corresponds to that described in the EMM, except for the following differences:

- Opportunistic monitoring at station 6605 in upper Southam Canyon was not conducted during 1982, but will recommence in 1983. Major disturbances are not expected to occur in Southam Canyon until several years from now. Therefore, the objective of data collection at this station will be to increase the baseline data base, until processed shale disposal begins in this watershed. Station 6605 will then become the control station used for comparison to station 6610 at the mouth of Southam Canyon.
- Water quality sampling at station 6700 was conducted on a semi-annual basis during 1982, rather than quarterly as described in the EMM. Project activities during the 1982 water year generally involved earthwork for road and building pad construction. Since the potential sources with the highest priority ranking (in the EMM) are those related to processing activities, as opposed to construction activities, the water quality sampling scope and frequencies will be increased to meet EMM objectives at the appropriate time prior to initiation of associated project activities.

6.3.2 Bedrock Aquifers The bedrock aquifer monitoring wells are located so that they will detect project-related changes which may occur in ground water quality and storage. Wells located upgradient of project activities are designated control stations, and those located downgradient are designated treatment stations. The bedrock aquifer wells are completed so that they

receive ground water from the Uinta and Green River Formations. All but two of the wells receive water exclusively from the Birds Nest Zone located in the upper portion of Parachute Creek Member and above the mining zone. Well P-2 Upper is completed within a water bearing zone believed to be of limited areal extent and located near the contact of the lower Uinta and upper Green River Formations. This water bearing zone is referred to as the Upper Aquifer. Well P-4 was initially drilled past the Birds Nest Zone for investigation purposes, and then backfilled with grout up to the base of the Birds Nest Zone. The grout seal for this well is apparently imperfect since water level and quality data indicate that the well is also receiving water from the Douglas Creek Aquifer due to upward leakage. Well P-4 has been deleted from the 1983 program, and replaced with well G-14, in order to conform to the program described in the EMM.

The collection of baseline bedrock aquifer water quality data was suspended after the 1976 water year, because it was felt that additional data were not required during the lease suspension period due to the slow movement of ground water over time. It is planned that a final baseline water quality sample will be collected from each well during the 1983 water year prior to penetration of the Birds Nest Zone by the production decline and air ventilation shaft.

The water levels of four wells (P-1, P-2 Upper, P-2 Lower and P-3) have been monitored continuously since the beginning the baseline period. Other wells were monitored on a monthly basis during the first two baseline years and then on a semi-annual basis during the lease suspension period. In 1982, the water levels for certain of these wells began to show a decline compared to earlier records. Therefore, supplemental data were collected to better define the changes in water levels. The water level monitoring frequency for

these wells was upgraded to a quarterly basis by the end of the 1982 water year, which corresponds to the program described in the EMM.

6.3.3 Alluvial Ground Water The alluvial ground water monitoring program performed during the lease suspension period is much different from the program described in the EMM. During the first two years of the baseline period, a large number of wells throughout the project area were involved in the data collection program. The results provided the data base for alluvial ground water systems throughout the project area. The baseline program was then reduced to a few select wells. The scope of monitoring at each well was also reduced, with supplemental data collection efforts occurring when it was indicated that water quality, in particular, had changed in comparison to the earlier data. This "interim" program was carried forward into the 1982 water year. Thus, monitoring of water level and field water quality parameters was performed on a semi-annual basis, with some supplemental data collection, as necessary, at wells AG-6-1 in the Southam Canyon alluvium and wells AG-3-1 and AG-3-3 in the White River alluvium downstream of the tracts.

At the end of the 1982 water year, modifications were made to the program so that it would conform to the program described in the EMM. Monitoring at wells G-2A, G-4A and AG-7 in Southam Canyon was reinstituted in November 1982. Wells AG-3-1 and AG-3-3 will not be included in the 1983 program, since monitoring will concentrate on the areas in the immediate vicinity of project retention dams and impoundments following their construction. New wells described in the EMM will be installed when construction of the associated project facilities has been completed.

6.3.4 Precipitation/Evaporation The 1982 monitoring program for precipitation and evaporation corresponds with the program described in the EMM. The precipitation network includes 10 locations on and near the tracts

equipped with either continuous recording gauges or storage gauges. The evaporation network consists of two sunken pans, located in the Southam Canyon and Plant Site Wash drainages. The data collected at these stations are used in the interpretation of concurrent data for several disciplines. Long-term site-specific precipitation and evaporation data are also useful in the design of certain project components, such as processed shale disposal and revegetation activities.

6.3.5 Quality Assurance/Quality Control Program The purpose of the QA/QC program for the water resources monitoring program is to ensure the accuracy, precision, completeness, representativeness, and comparability of sampling data. The program design is described in the EMM and in a technical memorandum.

Methods employed in data collection throughout the project life are standard methods specified by the USGS and EPA. Personnel involved in data collection and analysis are thoroughly familiar with appropriate methodologies. All equipment is routinely checked and maintained to verify that it is in proper working condition. Records of calibration and standardization for equipment are kept in each instrument's history file.

Laboratory analysis for suspended sediment sample concentrations are performed in WRSOC's site laboratory trailer. The balance used for weighing samples is checked on a monthly or more frequent basis as part of the QA/QC program for the air resources monitoring program. Laboratory methods for determination of suspended sediment concentration are standard methods used by the USGS.

Laboratory analyses for all other water quality parameters in the water resources program are performed by the USGS Central Laboratory in Denver, Colorado. The USGS has performed all such laboratory analyses throughout the

life of the project. All water quality samples collected by WRSOC are properly preserved prior to and during shipment to the laboratory.

The internal QC program of the Central Laboratory involves checking: (1) chemical balance, (2) relation of residue on evaporation to calculated dissolved solids, (3) relation of specific conductance to residue on evaporation, and (4) relation of specific conductance to anions and cations. The QA program involves: (1) performance of time-critical analyses within allowable time, (2) use and documentation of standard laboratory procedures, (3) use of reference materials to monitor analyses, and (4) analytical review procedures prior to release of information. Additional details are provided in TWRI Book 5, Chapter A1 (Skougstad, et. al. 1979).

Additional QA efforts by the Central Laboratory involve: (1) distribution of reference samples to participating laboratories for determination of a most probable value for various constituents, and (2) submittal of the reference samples to the Central Laboratory as blind samples received from the various USGS District offices. Results of the reference sample program are distributed to the participating laboratories and those USGS Districts using such outside laboratories. Results of the blind sample program are distributed within the USGS (Janzer 1983).

VTN personnel routinely perform informal technical reviews of data collection and analysis efforts to verify that QA/QC procedures are being followed. This involves periodic visits to the project site to inspect the actual performance of the hydrographer(s) and the condition of monitoring stations and equipment. All data collected by WRSOC and VTN personnel are reviewed by qualified VTN staff members. Processing of digital tapes is done by VTN staff using the WRSOC water resources computer programs, which are comparable to those used by the USGS for data processing. All water resources data are

are stored within the WRSOC water resources data management system (located at VTN's office in Irvine, California). This system is compatible with the USGS data management system, WATSTORE.

An independent QC audit of WRSOC water resources equipment was performed in August 1982 by WATEC, Inc., a consulting firm located in Aurora, Colorado. This has been conducted once a year for the past several years. The scope of this audit involves: (1) checking and calibration of all water quality equipment used in the water resources program, using additional known references provided by WATEC, Inc. where possible; (2) inspection of suspended sediment laboratory equipment; (3) inspection of all hydrologic equipment used for the water resources program, such as current meters and stage recorders; and (4) submittal of a report to WRSOC and VTN describing the findings of the audit and corrective actions taken. This year's audit did not indicate any significant QA/QC problems with WRSOC equipment, except for the gradual deterioration of the conductivity and temperature probes and cables used for continuous monitoring. The temperature probes and cables are being repaired and replaced using spare equipment. New conductivity probes and cables will be installed as soon as possible.

6.4 PROGRAM RESULTS AND ANALYSIS

6.4.1 Surface Water The following discussion of program results and analysis for surface water data is divided into three general topics: streamflow, suspended sediment and water quality. Discussions specific to each watershed/station are presented as subheadings under each general topic.

Project-related activities during 1982 were restricted primarily to the Plant Site Wash drainage and unnamed small tributaries to the White River located between the Plant Site Wash and Evacuation Creek watersheds. The Southam Canyon, Asphalt Wash and Evacuation Creek watersheds were not significantly disturbed in a hydrologic sense by project-related activities during the year. Of the surface water stations currently operated, only station 6602 in the Plant Site Wash and station 6700 on the White River downstream of the tracts should be considered as having entered the construction phase monitoring period. The remaining stations are still in the baseline period phase, with the exception of stations 6395 and 6625 which serve as control stations that will not be affected by present or future project-related activities.

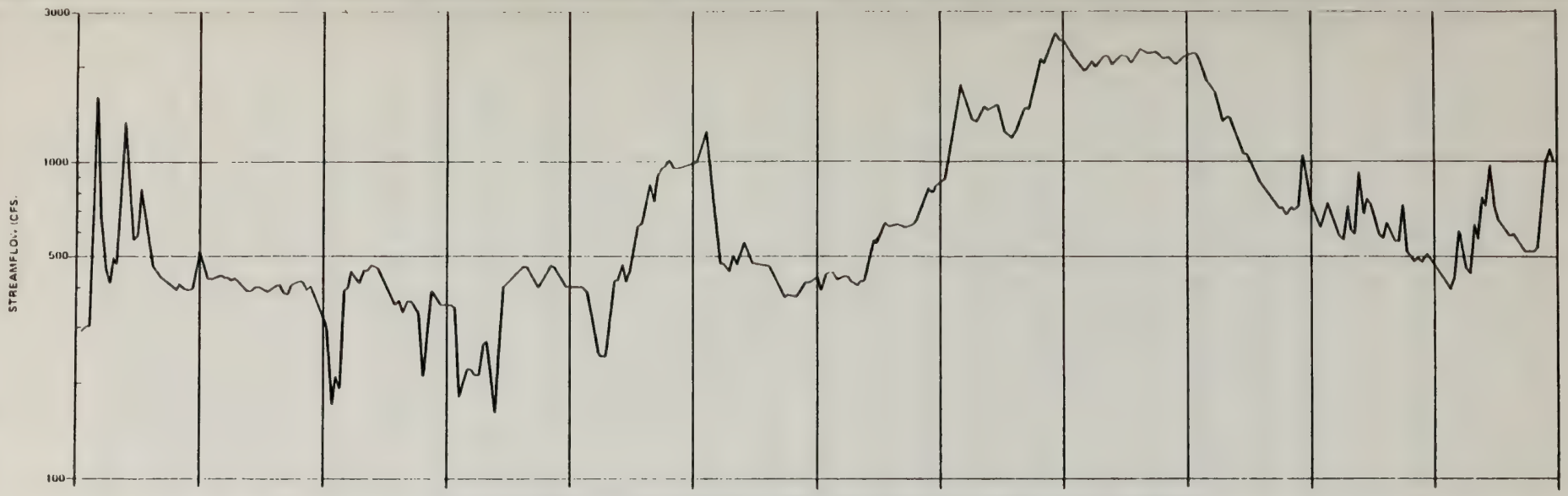
6.4.1.1 Streamflow

A. White River. The White River drainage can be divided into upper a lower basins, in terms of sources of streamflow. This has been previously described in the Final Environmental Baseline Report (VTN 1977) for this project and is also described by the USGS in Lindskov and Kimball (1982). This USGS open-file report divided the flow from the two basins into high flow and baseflow periods, primarily for interpretative use in the water quality discussions. Previous WRSOC reports had not differentiated between low flow from the two basins; they were grouped together and termed "baseflow". The differences can be described in a simple manner as follows: lower basin baseflow occurs during the summer when evapotranspiration and irrigation usage are

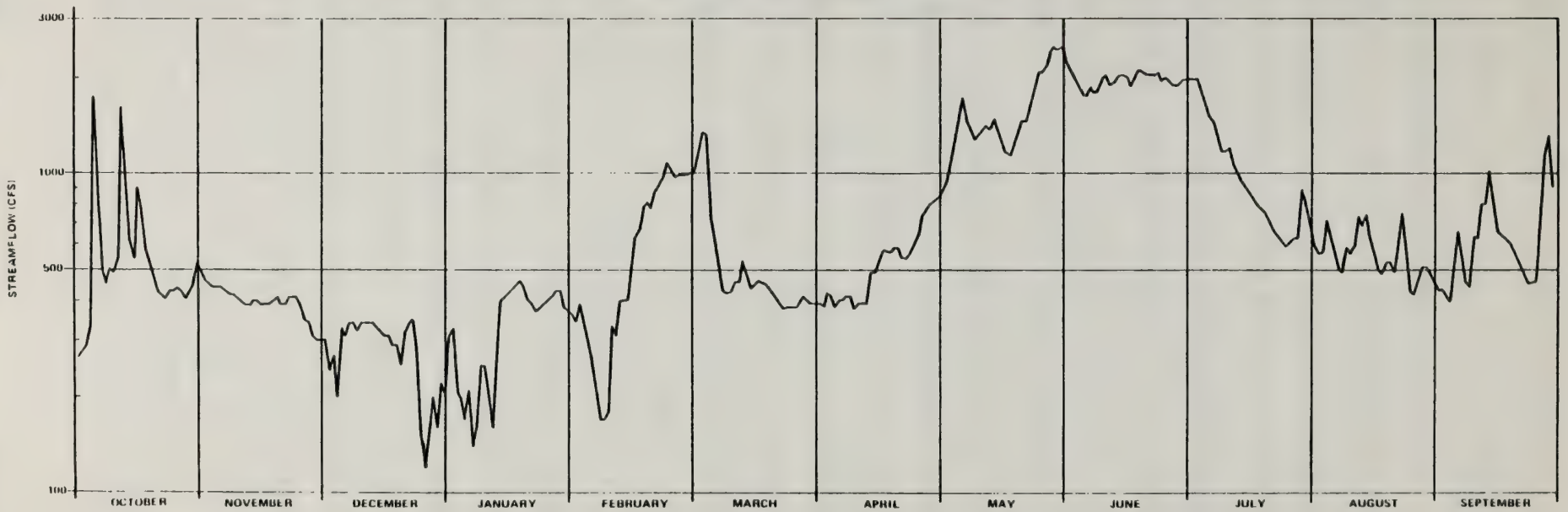
high, whereas upper basin baseflow occurs during the winter when evapotranspiration is low and there is no irrigation usage. This newer system of nomenclature will be used throughout this section.

Hydrographs depicting the 1982 flow regimes at stations 6395 and 6700 are shown in Figure 6.4-1. Thunderstorm runoff, primarily from within the lower basin, produced several short-term flow increases during October 1981 and late July through September 1982. Snowmelt runoff from the lower basin occurred from mid-February through mid-March 1982. Snowmelt runoff from the upper basin occurred from mid-April through late July 1982. The upper basin baseflow period was from late October 1981 through mid-February 1982. Lower basin baseflow occurred over relatively short periods of time in between storm runoff in October 1981 and late July through September 1982. The division between periods is based on which flow source is dominant. Frequently there is a transition period where sources of flow are fairly equally mixed, making the division unclear. This will be discussed in further detail in Section 6.4.1.3.

Lindskov and Kimball (1982) provide a daily duration hydrograph for station 6500 on the White River based on water years 1924 through 1979. The daily-duration hydrograph describes daily mean flows corresponding to particular percentages of time that flow was equal to or greater than values shown. Comparison of the 1982 streamflow records for the White River stations to this daily-duration hydrograph reveals several observations. The 5 and 10 percentile flow values indicate numerous short-term peaks during October and July through September, similar to events during the 1982 water year. The 95 percentile flow values indicate several short-term low flow periods between 100 and 200 cfs during December and January. These are due to severe freezing conditions and loss of flow to ice formation. Similar conditions can be seen



WHITE RIVER NEAR COLORADO STATE LINE, UTAH (STA. NO. 09306395)
MEAN DAILY STREAMFLOW
OCTOBER 1981 – SEPTEMBER 1982



WHITE RIVER BELOW ASPHALT WASH, NEAR WATSON, UTAH (STA. NO. 09306700)
MEAN DAILY STREAMFLOW
OCTOBER 1981 – SEPTEMBER 1982

FIGURE 6.4-1

in the 1982 winter record. Using the 50 percentile flow values as being representative of the typical condition that would be expected for any single day during a year, it is apparent that 1982 lower basin snowmelt runoff began approximately a month earlier than is typical and its peak was of greater magnitude than usual. Also, snowmelt runoff from the upper basin began at the typically expected time of year during 1982 but persisted approximately two weeks longer than usual. The magnitude of the 1982 peak upper basin snowmelt runoff was similar to the peak for the 50 percentile flow values.

The maximum instantaneous discharge during the 1982 water year was 2,720 cfs on May 29, 1982 at station 6395, and 2,850 cfs on October 5, 1981 at station 6700. These values rank fairly low when compared to the long-term record for station 6500. The minimum daily discharge during the year was 160 cfs at station 6395 and 120 cfs at station 6700. Using the annual low flow frequency curve for station 6500 based on water years 1924 through 1979 as presented in Lindskov and Kimball (1982), the recurrence intervals of these annual one-day low flow values are estimated to be 3 and 5 years, respectively.

The 1982 annual runoff for station 6395 was 573,200 acre-feet, with an annual mean flow value of 792 cfs. Annual runoff for station 6700 was 538,900 acre-feet, with an annual mean flow value of 744 cfs. These values indicate that 1982 runoff was well above the long-term average runoff for station 6500, which is 502,300 acre-feet (695 cfs). For example, the value of 792 cfs for station 6395 would rank as the 45th value out of 56 years (rank=1 is the lowest value; rank=56 is the highest value) of record at station 6500. This is slightly above the 75th precentile of this record.

The streamflow records for stations 6395 and 6700 indicate that there was an apparent decrease in annual runoff (34,300 acre-feet) between stations

during 1982, despite the contributions of tributaries. This apparent decrease amounts to 6.0% of the annual runoff at station 6395. Contributions of tributaries between the two stations are minor compared to the measured loss in runoff. The major portion of this apparent loss occurred during December 1981 and April through August 1982. Potential actual losses include evaporation, consumptive use by phreatophytes (primarily during the freeze-free period) and water supply diversion by American Gilsonite Company and contractors employed by WRSOC and others. It is believed that the measured decreases in monthly streamflow between stations are greater than can be accounted for by the above actual losses for certain periods of time. Therefore, the inconsistency may be due to differences in assumptions for record computations and/or measurement errors. These will be investigated in further detail during 1983.

B. Evacuation Creek Mean daily discharge values for station 6430 during the 1982 water year are listed in Table 6.4-1. The data indicate that the streamflow of Evacuation Creek was sustained by baseflow through most of the year. Snowmelt runoff occurred in February, which was earlier in the year and quite brief compared to previous years. The flow during snowmelt runoff fluctuated widely during each day, peaking near midnight on each day. Runoff from thunderstorms produced numerous short duration rises in streamflow during October 1981 and July through September 1982. Thunderstorm runoff accounted for the majority of the 1982 annual runoff from Evacuation Creek. There were 18 daily peak flows over 100 cfs at this station during the 1982 water year. All but three of these peaks passed the station during the evening hours. This was primarily due to the lag time from the upper portions of the Evacuation Creek drainage where the intense thunderstorms were occurring.

The maximum instantaneous discharge during the year was 2,920 cfs on September 5, 1982. The minimum daily discharge was 0.03 cfs for several days

TABLE 6.4-1

EVACUATION CREEK NEAR MOUTH, NEAR WATSON, UTAH (STA. NO. 09306430)

MEAN DAILY DISCHARGE (CFS)
OCTOBER 1981 TO SEPTEMBER 1982

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	0.20	0.68	0.49	0.39	0.39	0.39	0.45	0.33	0.25	0.09	1.0	0.48
2	0.20	0.44	0.49	0.39	0.39	0.39	0.45	0.33	0.25	0.09	2.0	0.26
3	0.20	0.47	0.49	0.39	0.27	0.58	0.40	0.48	0.25	0.09	41	0.25
4	9.0	0.51	0.49	0.39	0.25	0.49	0.40	0.39	0.25	0.07	13	0.25
5	116	0.56	0.49	0.39	0.22	0.49	0.40	0.30	0.25	0.07	0.78	147
6	2.5	0.60	0.49	0.39	0.20	0.49	0.40	0.27	0.25	0.07	0.55	7.4
7	0.50	0.60	0.39	0.39	0.20	0.49	0.40	0.27	0.25	0.07	0.41	0.41
8	29	0.60	0.39	0.39	0.14	0.49	0.40	0.27	0.25	0.07	0.41	0.33
9	2.5	0.60	0.39	0.39	0.07	0.49	0.40	0.27	0.25	0.04	0.70	0.33
10	1.0	0.60	0.39	0.30	0.12	0.49	0.40	0.27	0.25	0.04	2.2	0.26
11	60	0.60	0.39	0.30	0.20	0.58	0.40	0.27	0.25	0.04	0.86	40
12	55	0.60	0.39	0.30	0.20	0.58	0.40	0.27	0.25	0.04	0.58	9.5
13	7.0	0.60	0.39	0.30	0.20	0.58	0.40	0.27	0.25	0.04	9.6	59
14	2.0	0.60	0.39	0.30	0.20	0.58	0.40	0.27	0.25	0.03	13	23
15	36	0.60	0.39	0.30	0.26	0.58	0.37	0.27	0.25	0.03	0.15	2.0
16	56	0.60	0.39	0.30	34	0.58	0.37	0.27	0.25	0.03	7.0	1.0
17	7.0	0.60	0.39	0.27	44	0.58	0.37	0.27	0.25	0.03	6.5	0.50
18	2.0	0.60	0.39	0.27	22	0.58	0.37	0.27	0.25	0.03	0.25	0.25
19	1.0	0.60	0.39	0.27	19	0.58	0.33	0.27	0.22	0.03	0.20	19
20	0.80	0.53	0.39	0.27	18	0.58	0.33	0.27	0.20	0.03	0.15	7.0
21	0.77	0.53	0.39	0.27	14	0.49	0.33	0.25	0.20	0.03	63	2.5
22	0.77	0.53	0.39	0.27	11	0.49	0.33	0.25	0.20	0.03	96	1.0
23	0.77	0.53	0.39	0.27	7.0	0.49	0.33	0.27	0.20	0.03	50	0.80
24	0.68	0.53	0.39	0.27	2.2	0.49	0.33	0.27	0.17	0.03	15	0.70
25	0.68	0.53	0.39	0.27	0.60	0.49	0.33	0.27	0.14	0.03	1.0	0.70
26	0.68	0.53	0.39	0.27	1.0	0.49	0.33	0.25	0.14	0.03	0.26	0.70
27	0.68	0.53	0.39	0.39	0.26	0.49	0.33	0.25	0.14	0.27	0.33	49
28	0.68	0.53	0.39	0.58	0.33	0.49	0.33	0.25	0.14	10	0.48	81
29	0.58	0.53	0.39	0.49	0.41	0.49	0.33	0.25	0.12	11	0.18	40
30	0.49	0.53	0.39	0.49	—	0.45	0.33	0.25	0.12	2.1	1.6	5.0
31	0.68	—	0.39	0.58	—	0.45	—	0.25	—	1.2	5.5	—
TOTAL	395	17	13	11	177	16	11	8.7	6.5	26	334	500
MEAN	13	0.57	0.41	0.35	6.1	0.52	0.38	0.29	0.22	0.84	11	17
MAX.	116	0.68	0.49	0.58	44	0.58	0.45	0.48	0.25	11	96	147
MIN.	0.20	0.44	0.39	0.27	0.07	0.39	0.33	0.25	0.12	0.03	0.15	0.25
AC-FT	784	34	25	22	351	32	22	17	13	51	662	991

WTR YR 1982 TOTAL: 1514 MEAN: 4.1 MAX: 147 MIN: 0.03 ACRE-FT: - 3003

in July. Total annual runoff for the 1982 water year was 3,003 acre-feet. Both the maximum instantaneous discharge and the annual runoff are the highest values for the 8-year record at station 6430.

C. Dry Washes. Station 6610 at the mouth of Southam Canyon recorded an annual runoff of 92 acre-feet during the year. This was the second highest amount during the eight years of record, and considerably above the average for the period (32 acre-feet). All dry washes in the southeastern Uinta Basin have shown great variability in annual flows. The average annual unit runoff for the period of record at this station, 0.0055 cfs/mi^2, corresponds closely with the USGS estimate of less than 0.005 cfs/mi^2 for this area (Lindskov and Kimball 1982). The maximum instantaneous discharge during the year, 107 cfs on August 2, 1982, is the third highest value in the 8-year period of record.

Station 6602 near the mouth of Plant Site Wash recorded 7.9 acre-feet of runoff during the 1982 water year. This amounts to an annual unit runoff of 0.0082 cfs/mi^2. The maximum instantaneous discharge during the year was 43 cfs on August 2, 1982.

The 1982 discharge record for station 6625 near the mouth of Asphalt Wash is not available at the present time. However, it is known that a major flash flood did occur in early September 1982. Evidence from a site visit after the flood suggested that it was probably similar in magnitude to the flash flood on August 25, 1980 at this station. This previous event had a peak discharge of 3,200 cfs.

Lindskov and Kimball (1982) presented a method to estimate peak flows that are exceeded less frequently than the mean annual peak flow. The relationship used in this method was based on long-term records for two Willow Creek gauging stations (09307500 and 09308000). It was determined that the peak

discharge of the 100-year flood would be 15 times greater than the mean annual peak discharge for intra-area streams in the southeastern Uinta basin. The mean annual peak discharge for station 6610 over 8 years of record is 108 cfs. Using this value, the peak discharge of the 100-year flood at the mouth of Southam Canyon would be 1,620 cfs. This can be compared to an estimated value of 850 cfs, previously presented in the First Year Environmental Baseline Report (VTN 1976), which used a different method that did not involve the application of site-specific flow records. Both estimates involve considerable errors inherent to each specific method; therefore, caution is advised for use of these values. The best estimate for the 100-year flood at a particular location would be determined from analysis of flow records over a sufficient time period (e.g., more than 20 years) at that location, and would be based on a uniformly accepted method (e.g., one recommended by the U.S. Water Resources Council).

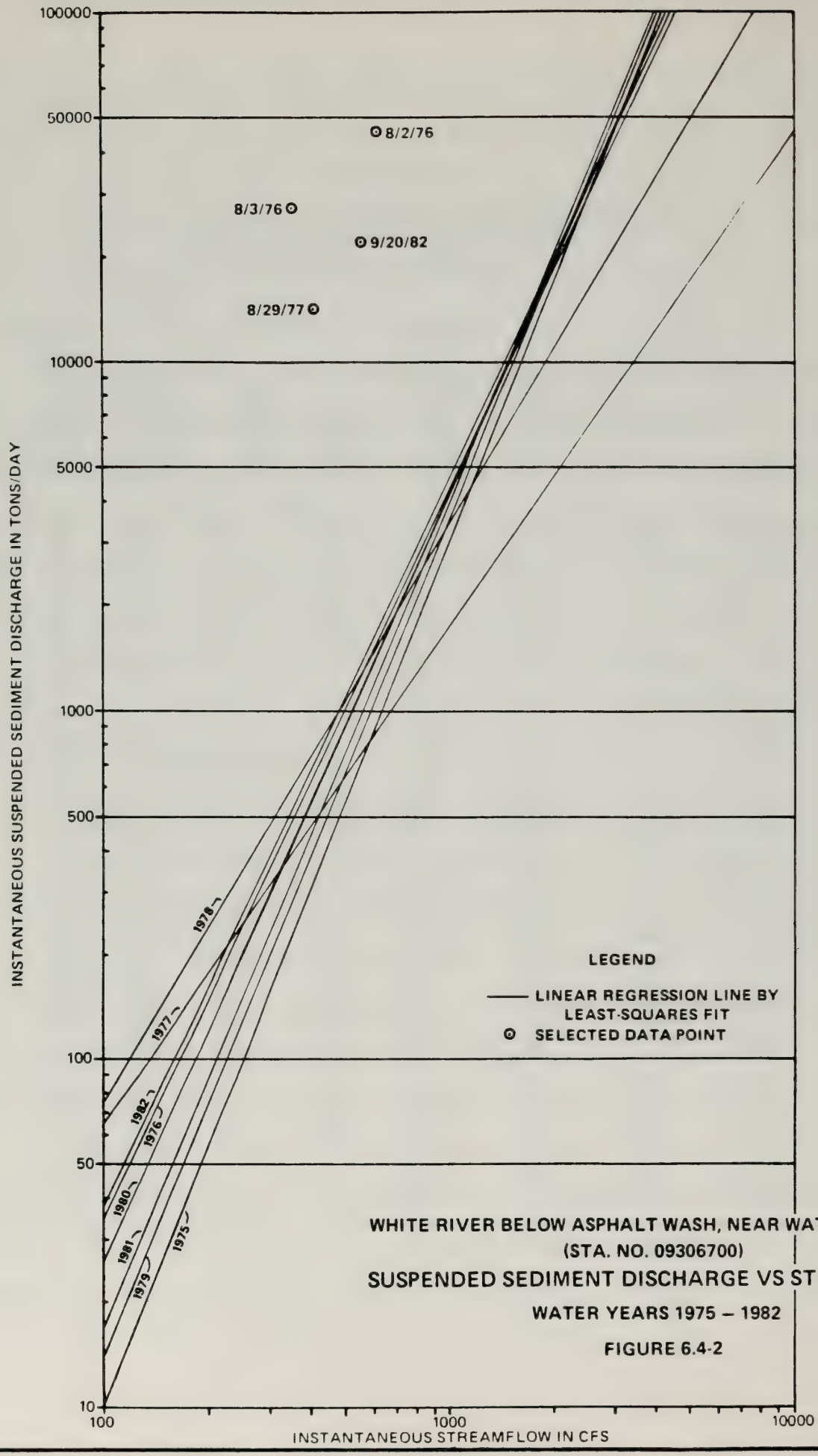
6.4.1.2 Suspended Sediment

A. White River. Suspended sediment (SS) data collected at station 6700 during the 1982 water year are shown in Table 6.4-2. The 1982 data were analyzed by plotting the instantaneous SS discharge rate versus the instantaneous flow rate on logarithmic paper. The plotted points define a rating curve similar to the curve for previous years of record (Figure 6.4-2). However, one data point (September 20, 1982) plotted significantly apart from the other points for 1982. Previous years of record for this station were reviewed to determine if a similar situation had occurred in the past. Three data points were found to plot in a similar manner. These were for August 2 and 3, 1976 and August 29, 1977. All four points (one during 1982 and three during the baseline period) were determined to have occurred during or immediately following rapid rises in streamflow due to thunderstorm runoff. The rapid

TABLE 6.4-2

WHITE RIVER BELOW ASPHALT WASH, NEAR WATSON, UTAH (STA. NO. 09306700)
FIELD WATER QUALITY AND SUSPENDED SEDIMENT DATA
OCTOBER 1981 - SEPTEMBER 1982

DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	WATER TEMPER-ATURE (DEG C)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	PH FIELD (UNITS)	DIS-SOLVED OXYGEN (MG/L)	SEDI-MENT, SUS-PENDED (MG/L)	SUSP SEDI-MENT DIS-CHARGE (T/DAY)
10/01/81	1030	267	12.0	760	7.4	8.8	284	205
10/21/81	1130	430	8.0	830	8.2	9.2	806	936
11/09/81	1130	426	5.0	880	8.6	10.2	341	392
12/01/81	1050	307	0.0	950	—	10.8	248	206
12/16/81	1020	E270	0.0	800	8.6	11.2	340	248
01/04/82	1045	200	0.0	850	8.2	9.8	50	27
01/21/82	1245	407	—	—	—	—	282	310
01/28/82	0930	408	0.0	850	—	—	—	—
02/08/82	1000	176	0.0	1200	8.2	11.4	167	79
03/05/82	1030	717	0.5	900	8.4	—	4640	8980
03/16/82	1000	440	6.5	1000	8.6	10.0	732	870
04/02/82	1200	352	8.0	950	8.6	10.0	290	276
04/13/82	0915	390	15.5	950	8.4	8.9	473	498
04/20/82	1200	584	6.5	—	8.0	10.2	1390	2190
04/27/82	1220	714	13.5	670	8.4	8.4	2250	4340
05/04/82	1145	1370	14.5	560	7.8	8.0	7020	26000
05/13/82	1115	1360	10.0	440	—	8.8	2570	9440
05/26/82	1130	2050	15.0	350	8.2	8.2	3350	18500
06/04/82	1145	1910	15.0	340	8.3	8.0	2110	10900
06/15/82	1100	2050	14.5	338	7.8	7.8	1710	9470
06/22/82	1130	2020	15.5	310	8.2	7.6	1320	7200
07/01/82	1225	1990	17.5	310	7.0	7.8	1360	7310
07/08/82	1215	1310	19.0	380	8.2	7.5	1200	4240
07/17/82	0810	825	19.5	465	7.4	—	605	1350
07/27/82	1100	622	23.0	470	7.8	6.8	750	1260
08/05/82	1145	605	21.0	600	7.8	7.0	2390	3900
08/12/82	1015	530	21.0	650	7.7	6.6	4320	6180
08/19/82	0945	E560	21.0	690	—	—	2160	3270
09/01/82	1000	454	19.0	700	8.2	7.6	1930	2370
09/20/82	1100	562	16.0	820	8.0	7.6	14600	22200



WHITE RIVER BELOW ASPHALT WASH, NEAR WATSON, UTAH
(STA. NO. 09306700)
SUSPENDED SEDIMENT DISCHARGE VS STREAMFLOW
WATER YEARS 1975 – 1982
FIGURE 6.4-2

rises in streamflow were caused by flash floods from drainages in the lower basin. As shown in Figure 6.4-2, the SS transport rate during such periods is much greater than is typical for a comparable streamflow rate. Such modifications to the typical SS transport characteristics of the White River are short-term, and are the result of the variations in sediment yield between the upper and lower basins. Seiler and Tooley (1982) have pointed out that runoff contributions from lower basin tributaries have been observed to cause sharp increases in SS discharge without much effect on the streamflow of the White River, thereby producing a large scatter of points (on the graphical plot) for streamflow values between 300 and 800 cfs. Their observations are based on an analysis of data collected by the USGS at station 6900 (at the mouth of the White River) during the 1975 through 1979 water years.

The SS data collected at station 6395 by the USGS during the 1982 water year are not available at the present time. Therefore, comparisons between 1982 data for station 6395 and 6700 are not included in this report.

In summary, the analysis of 1982 SS data for station 6700 leads to several observations. First, the typical SS transport characteristics of the White River at this station during 1982 were similar to those for previous years. The magnitudes of SS discharge vary with flow conditions; however, the relationship of SS discharge to streamflow has remained relatively constant. Second, exceptions to this typical relationship occur during and immediately following certain thunderstorm runoff periods. During such periods, the SS transport rate is higher than usual for the flow rate involved. These occurrences are due to variations of natural erosion characteristics within the White River drainage. In conclusion, the available data indicate that project activities during the 1982 water year did not have a significant impact on the SS transport characteristics of the White River downstream of the tracts.

B. Evacuation Creek SS data for station 6430 during the 1982 water year are shown in Table 6.4-3. The values shown for October 4, 1981 and August 3, 1982 are for samples collected by a single-stage sampler, and are indicated by the "E" preceding the SS concentration value.

As in previous years, the data illustrate that SS transport characteristics of Evacuation Creek fluctuate widely due to variations in streamflow. During stable low flow periods, SS concentrations were generally less than 300 mg/l, and SS discharge was less than 1 ton/day. The SS concentration and discharge rate were much greater during high flow periods, as compared to stable baseflow periods. SS concentration and discharge values during snowmelt runoff were generally less than values during thunderstorm runoff for similar streamflow rates. This is a typical situation, and is due primarily to the fact that snowmelt runoff generally involves more gradual rises in stage than thunderstorm runoff and produces less erosion. SS transport was greatest during the thunderstorm runoff periods, which usually account for most of the annual SS discharge. The values for September 27 are not as high as values previously collected on July 5, 1977 during thunderstorm runoff. On that date, the USGS collected a sample at 456 cfs which had a SS concentration of 178,000 mg/l and an instantaneous SS discharge rate of 219,000 tons/day. A second sample on that date at 247 cfs had values of 164,000 mg/l and 109,000 tons/day. The SS concentration values for October 4, 1981 and August 3, 1982 are also less than other single-stage sampler values collected during previous years. Additional analyses of the natural erosion and sediment characteristics of Evacuation Creek were presented in Seiler and Tooley (1982). These studies were based on data collected by the USGS during the 1975 through 1979 water years. The reader is referred to this report for additional information on this drainage.

TABLE 6.4-3

EVACUATION CREEK NEAR MOUTH, NEAR WATSON, UTAH (STA. NO. 09306430)
FIELD WATER QUALITY AND SUSPENDED SEDIMENT DATA
OCTOBER 1981 - SEPTEMBER 1982

DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	WATER TEMPER-ATURE (DEG C)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	PH FIELD (UNITS)	DIS-SOLVED OXYGEN (MG/L)	SEDI-MENT, SUS-PENDED (MG/L)	SUSP SEDI-MENT DIS-CHARGE (T/DAY)
10/04/81	2200	E70	--	--	--	--	E270000	51000
10/04/81	2400	E138	--	--	--	--	65800	24500
10/05/81	1120	E48	10.0	590	8.3	9.2	35400	4590
10/20/81	1205	0.78	15.5	4100	7.5	8.0	57	0.12
11/02/81	1115	0.43	13.0	4000	8.0	--	40	0.05
12/02/81	1130	0.53	9.5	4000	8.0	--	70	0.10
01/05/82	1110	0.35	6.0	--	7.5	9.6	43	0.04
01/28/82	1100	E0.20	5.5	4700	--	--	--	--
02/01/82	1205	0.45	9.5	4800	8.0	10.4	41	0.05
02/16/82	1145	19	0.0	1600	7.0	9.6	1720	88
02/19/82	1000	E11	0.0	1500	8.0	10.0	1560	46
02/22/82	1000	9.0	0.0	1500	8.0	--	10500	255
03/01/82	1100	0.42	10.5	4400	8.0	--	51	0.06
04/01/82	1130	0.45	13.0	4500	--	11.2	174	0.21
04/21/82	1220	0.33	18.0	4600	8.2	10.2	229	0.20
04/29/82	1000	E0.31	14.0	4600	8.2	8.8	--	--
05/12/82	1120	0.26	12.0	4800	6.8	10.0	90	0.06
05/24/82	1350	0.26	24.0	4100	6.8	--	121	0.09
06/03/82	1055	0.25	19.5	4800	6.8	9.8	231	0.16
06/17/82	0950	0.25	21.0	4700	7.0	7.8	109	0.07
07/06/82	1220	0.08	26.0	4800	7.0	7.2	160	0.04
07/16/82	1100	0.03	22.5	4900	6.7	--	40	0.00
07/28/82	1145	0.23	22.5	3250	6.0	5.8	71200	44

TABLE 6.4-3 (CONTINUED)

DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	WATER TEMPER-ATURE (DEG C)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	PH FIELD (UNITS)	DIS-SOLVED OXYGEN (MG/L)	SEDI-MENT, SUS-PENDED (MG/L)	SUSP SEDI-MENT DIS-CHARGE (T/DAY)
08/03/82	2000	E568	--	--	--	--	E273000	419000
08/04/82	1000	6.5	17.0	1150	7.2	6.4	63900	1120
08/10/82	1130	2.7	22.5	1400	7.3	7.0	65700	486
08/11/82	1030	E0.33	23.0	4000	7.0	6.9	--	--
08/11/82	1115	2.0	--	--	--	--	25000	135
08/16/82	1130	0.07	24.5	4400	8.8	6.6	132	0.03
08/25/82	0900	0.63	18.5	4000	8.6	--	763	1.3
09/03/82	1030	0.25	16.0	3100	8.0	6.8	92	0.06
09/16/82	1230	0.94	20.0	3950	7.6	6.6	222	0.56
09/24/82	0920	0.71	12.0	3600	8.1	7.6	149	0.29
09/27/82	1100	E280	12.5	820	7.8	--	114000	86200

In summary, the SS transport characteristics of Evacuation Creek at station 6430 during the 1982 water year were within ranges described by previously collected data. Although daily, monthly and annual SS discharge values were not calculated, the 1982 annual SS discharge would most likely be greater than in the 1975 through 1981 water years, because there were more large thunderstorm runoff events during 1982 than in these previous years. There were no significant project-related disturbances within this drainage; therefore, it is likely that observed SS transport characteristics were caused by the hydrologic system's response to natural variations in climatic conditions.

C. Dry Washes. The SS data collected at stations 6602 and 6610 during the 1982 water year are shown in Table 6.4-4. As in the previous instances, the SS data values for bottles collected by the single-stage samplers are indicated by an "E" preceding the value of SS concentration. The USGS was not able to collect any SS samples at station 6625 during the year.

Data for station 6610 were analyzed by plotting instantaneous SS discharge versus the instantaneous flow rate on logarithmic paper (Figure 6.4-3). Due to the limited amount of available data, the values for samples collected by the single-stage sampler were included on the plot, using a separate symbol to differentiate them from the manually collected sample values. The plotted points for station 6610 describe a relatively good relationship of SS discharge to flow (correlation coefficient = 0.98, $p<0.01$, $n=8$). Data for samples collected at less than 1 cfs were deleted from the statistical analysis. Values for the 1982 water year followed the relationship for the previously collected data, indicating that SS transport characteristics for this station have remained constant.

TABLE 6.4-4

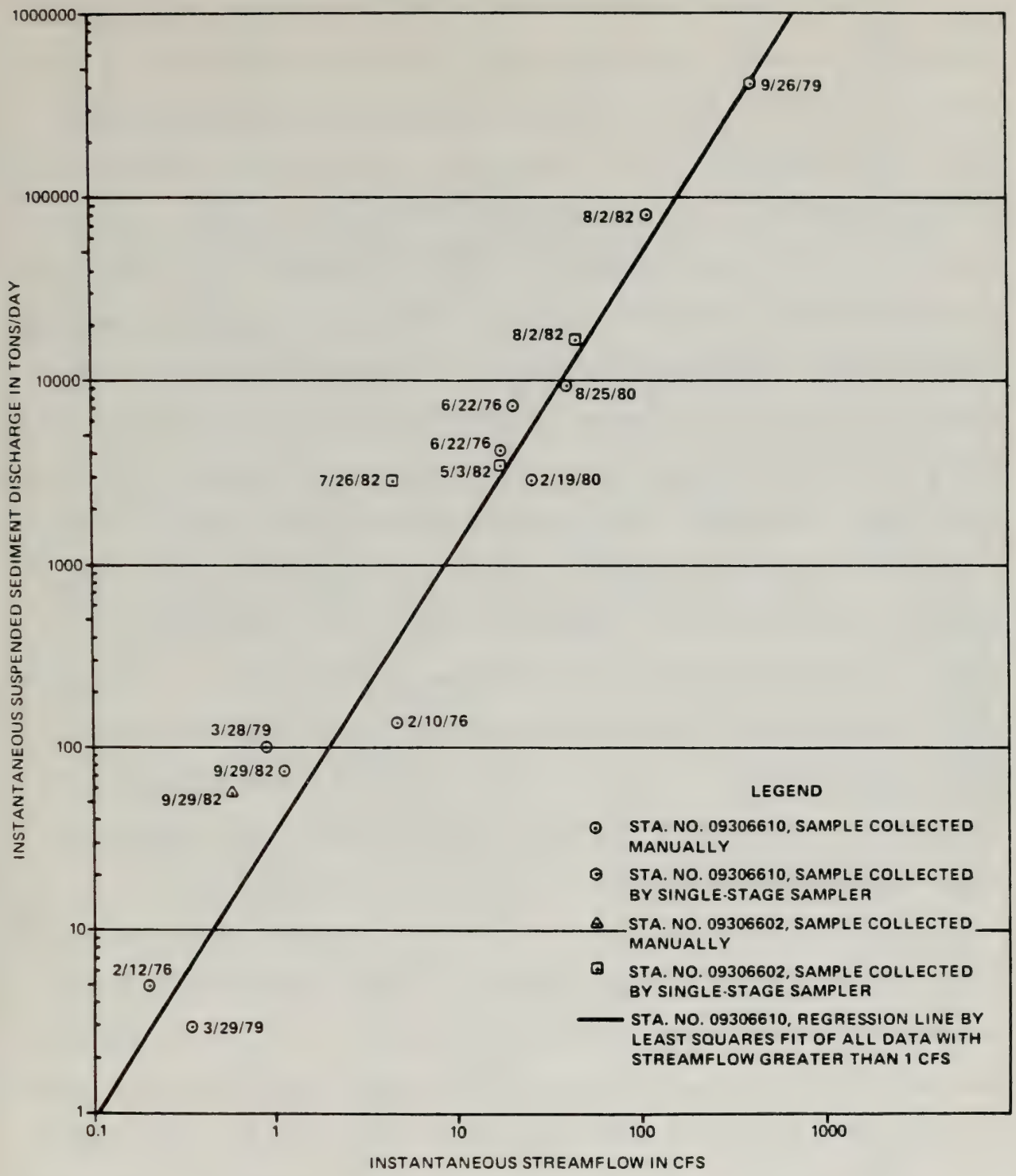
PLANT SITE WASH (STA. NO. 09306602) AND SOUTHAM CANYON WASH AT MOUTH, NEAR WATSON, UTAH (STA. NO. 09306610)
FIELD WATER QUALITY AND SUSPENDED SEDIMENT DATA
OCTOBER 1981 - SEPTEMBER 1982

PLANT SITE WASH (STA. NO. 09306602)

DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	WATER TEMPER-ATURE (DEG C)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	PH FIELD (UNITS)	DIS-SOLVED OXYGEN (MG/L)	SEDI-MENT, SUS-PENDED (MG/L)	SUSP SEDI-MENT DIS-CHARGE (T/DAY)
05/03/82	1930	E17	—	—	—	—	E74800	3430
07/26/82	2345	E4.4	—	—	—	—	E238000	2820
08/02/82	1800	E43	—	—	—	—	E140000	16300
09/13/82	1400	E0.90	11.0	200	—	—	—	—
09/29/82	0900	0.58	6.0	375	7.0	10.8	36500	57

SOUTHAM CANYON WASH (STA. NO. 09306610)

DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	WATER TEMPER-ATURE (DEG C)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	PH FIELD (UNITS)	DIS-SOLVED OXYGEN (MG/L)	SEDI-MENT, SUS-PENDED (MG/L)	SUSP SEDI-MENT DIS-CHARGE (T/DAY)
08/02/82	1810	E107	—	—	—	—	E273000	78900
09/29/82	1015	1.1	7.0	585	7.2	10.2	23800	71



SOUTHAM CANYON (STA. NO. 09306610) AND
PLANT SITE WASH (STA. NO. 09306602)

SUSPENDED SEDIMENT DISCHARGE VS STREAMFLOW

WATER YEARS 1975 – 1982

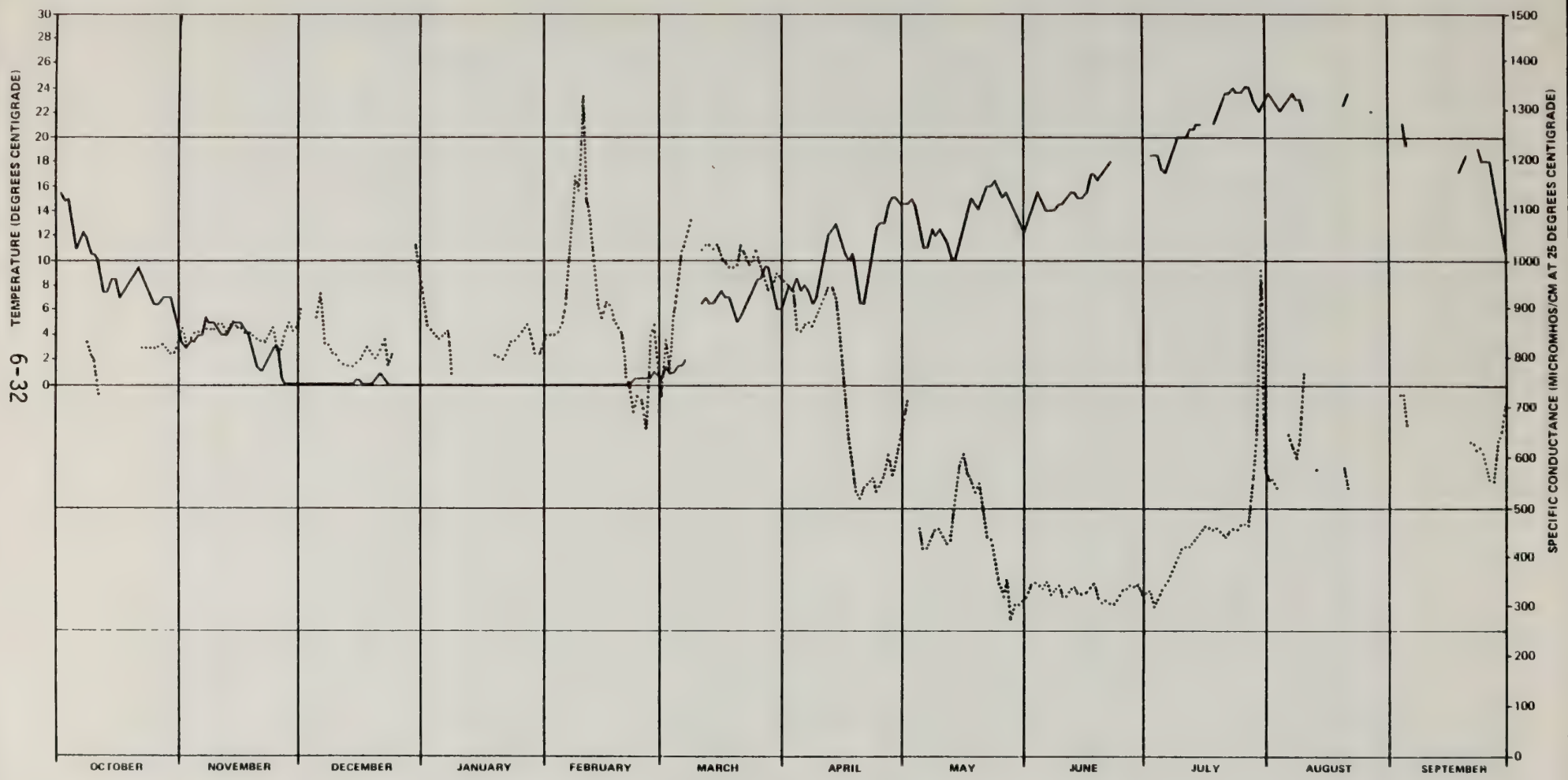
FIGURE 6.4-3

In order to determine whether similarities exist between drainages, the 1982 values for station 6602 were plotted against all data for station 6610 (also shown in Figure 6.4-3). Two of the plotted points for station 6602 (May 3, 1982 and August 2, 1982) were close to the regression line for station 6610, by inspection. The remaining two plotted points (July 26, 1982 and September 29, 1982) were considerably above the regression line. These two points correspond to samples collected at lower flow rates than the May 3 and August 2 samples. Regional SS particle size data indicate that the finer fractions, silt and clay, make up a greater percentage of the mass of a SS sample during low flow conditions than during high flow conditions (Seiler and Tooley 1982). Therefore, if SS transport at similar flow rates was notably greater for station 6602 than for station 6610 during low flow conditions, then this could be caused by increased transport of the finer-grained particles within the Plant Site Wash drainage. Construction activities during 1982 would undoubtedly have increased the availability of fine-grained particles within this drainage. It is probable that increased transport of fine-grained material would be masked out during higher flows, because the percentage of fines would be much less than for lower flow rates.

Based on these observations, it is concluded that project-related activities affected SS transport characteristics of Plant Site Wash by increasing the quantity of fine-grained sediment within runoff. Also, this effect was noticeable only during smaller runoff events. Due to the relative quantities involved, the modification of SS transport characteristics for the Plant Site Wash drainage probably did not significantly affect the White River downstream of the confluence.

6.4.1.3 Water Quality

A. White River. The 1982 mean daily values of temperature and specific conductance at station 6700 are shown in Figure 6.4-4. Supplemental field



LEGEND

——— TEMPERATURE

····· SPECIFIC CONDUCTANCE

WHITE RIVER BELOW ASPHALT WASH, NEAR WATSON, UTAH (STA. NO. 09306700)

MEAN DAILY TEMPERATURE AND SPECIFIC CONDUCTANCE

OCTOBER 1981 – SEPTEMBER 1982

FIGURE 6.4-4

measurements of water temperature, specific conductance, pH, and dissolved oxygen at station 6700 are listed in Table 6.4-2, previously presented in Section 6.4.1.2.

Recorded water temperatures at station 6700 ranged from 0.0°C to 26.0°C, and averaged 8.5°C during the year, with 87% data recovery (for valid mean daily values). The general pattern of water temperature was similar to all previous years of record. Historic records at station 6500 have ranged from 0°C to 33°, with an average of 10.4°C. Changes in water temperature of the White River have been shown to closely follow changes in air temperature, with a lag of 1 or 2 days. Year-to-year variations in water temperature are due to variations in annual air temperature (Lindskov and Kimball 1982).

Recorded specific conductance values at station 6700 ranged from 174 micromhos/cm to 1480 micromhos/cm during the year, with 79% data recovery (for valid mean daily values). The minimum value occurred during peak upper basin snowmelt runoff on May 28, 1982, while the maximum value occurred during lower basin thunderstorm runoff on July 30, 1982. These 1982 extreme values are within previously observed ranges for the White River stations. General patterns of specific conductance were similar to those from previous years. Conductivity data collected in 1982 illustrate an additional pattern which has not been emphasized in previous reports. That is, severe winter freezing conditions tend to reduce flow rates because of ice formation, and to elevate specific conductance at the same time. Examples of this situation can be clearly seen in late December 1981 and early February 1982 (see Figures 6.4-1 and 6.4-4).

Mean daily values of water temperature and specific conductance at station 6395 during the 1982 water year are not available at the present time. Several instantaneous field readings of specific conductance at station 6395

were made in 1982 when laboratory water quality samples were collected. These values are listed in Table 6.4-5, with the laboratory water quality data. Differences between the instantaneous field values at station 6395 and the corresponding mean daily values at station 6700 ranged from -6% to +15%. The USGS defines a good quality daily values record as one in which 95% of the daily values are accurate within ±10%. Thus, the differences in specific conductance between stations on these few days are considered to be relatively minor when measurement accuracies are taken into account. This is not necessarily the case throughout the year, since thunderstorm runoff from tributaries between the stations has been shown to have significant short-term effects on White River water quality. Further inter-station comparisons for 1982 cannot be made until the daily values record of specific conductance for station 6395 is available.

Values of pH ranged from 7.5 to 8.1 at station 6395, and from 7.0 to 8.6 at station 6700. The larger variation at station 6700 is probably due to the fact that many more readings were taken during the year. All values are within previously observed ranges. The pH of the White River has not shown a significant correlation with flow or to the concentration of any of the major constituents. There is some direct correlation to the concentration of dissolved solids. This is discussed in detail by Lindskov and Kimball (1982).

Dissolved oxygen concentrations ranged from 7.0 mg/l to 12.0 mg/l at station 6395, and from 6.6 mg/l to 11.4 mg/l at station 6700. Seasonal fluctuations were similar to those in previous years. Concentrations are generally near saturation through most of the year.

Up to this point, the discussion of White River water quality has been involved with those parameters that are monitored continuously (by probes and

TABLE 6.4-5
WHITE RIVER SHALE PROJECT: SURFACE WATER MONITORING STATIONS
WATER QUALTY DATA

OCTOBER 1981 TO SEPTEMBER 1982

STATION NUMBER	DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	WATER TEMPER-ATURE (DEG C)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	PH FIELD (UNITS)	DIS-SOLVED OXYGEN (MG/L)	COLOR (PCU)	TURBI-DITY (NTU)	SUS-PENDED SOLIDS, RESIDUE @ 105 C (MG/L)
09306395	10/07/81	1500	454	14.0	760	8.0	8.1	—	—	—
WHITE RIVER	10/27/81	1630	376	9.6	720	7.9	—	—	—	—
NEAR STATE LINE	11/24/81	1600	—	—	—	—	10.6	—	—	—
	12/23/81	1430	366	0.0	775	7.8	12.0	—	—	—
	01/26/82	1400	465	0.0	750	7.5	11.2	—	—	—
	03/25/82	1200	410	6.5	920	7.8	10.0	—	—	—
	05/07/82	1500	1520	9.5	415	7.6	8.7	—	—	—
	06/15/82	1000	2290	13.0	350	7.8	8.2	50	110	316
	07/15/82	1000	1040	19.0	485	8.0	7.6	—	—	—
	08/26/82	1400	520	22.5	600	8.1	7.0	—	—	—
09306430	01/28/82	1100	E0.20	5.5	4700	—	—	—	—	—
EVACUATION CREEK	04/29/82	1000	E0.31	14.0	4600	8.2	8.8	5	1.8	7
NEAR MOUTH	07/28/82	1145	0.23	22.5	3250	6.0	5.8	—	—	61800
09306602	09/29/82	0845	0.57	6.0	375	7.0	10.8	—	1200	8810
PLANT SITE WASH										
09306610	09/29/82	1015	1.1	7.0	585	7.2	10.2	150	1500	7410
SOUTHAM CANYON WASH										
09306700	01/28/82	0930	408	0.0	850	—	—	—	—	—
WHITE RIVER BELOW	06/15/82	1100	2050	14.5	338	7.8	7.8	50	190	438
ASPHALT WASH										

TABLE 6.4-5 (CONTINUED)

STATION NUMBER	DATE	TIME	DISS SOLIDS @180 C (TDS) (MG/L)	TOTAL DISS SOLIDS (SUM) (MG/L)	ALKALI-NITY, LAB (MG/L AS CACO3)	HARD-NESS TOTAL (AS CACO3) (MG/L)	HARD-NESS, NONCAR. (AS CACO3) (MG/L)	CALCIUM DISS (MG/L)	MAGNE-SIUM DISS (MG/L)	SODIUM DISS (MG/L)
09306395	10/07/81	1500	--	422	150	220	70	55	20	48
WHITE RIVER NEAR	10/27/81	1630	--	509	170	290	118	71	27	57
STATE LINE	11/24/81	1600	--	543	200	320	115	75	31	62
	12/23/81	1430	--	496	190	280	89	69	26	60
	01/26/82	1400	--	537	200	310	110	78	28	65
	03/25/82	1200	--	619	200	330	130	76	34	77
	05/07/82	1500	--	244	126	170	43	43	15	22
	06/15/82	1000	218	213	119	160	40	44	12	13
	07/15/82	1000	--	294	150	200	52	53	17	22
	08/26/82	1400	--	420	177	250	72	62	23	45
09306430	01/28/82	1100	--	4010	450	1200	757	170	190	800
EVACUATION CREEK	04/29/82	1000	4710	3790	390	1200	825	190	180	810
NEAR MOUTH	07/28/82	1145	2840	2930	593	860	268	180	100	540
09306602	09/29/82	0845	270	276	107	48	0	15	2.4	79
PLANT SITE WASH										
09306610	09/29/82	1015	372	360	148	79	0	28	2.0	94
SOUTHAM CANYON WASH										
09306700	01/28/82	0930	--	511	200	290	85	71	26	31
WHITE RIVER BELOW	06/15/82	1100	222	215	119	160	38	43	12	13
ASHPHALT WASH										

TABLE 6.4-5 (CONTINUED)

STATION NUMBER	DATE	TIME	SODIUM ADSORP-TION RATIO (SAR)	PERCENT SODIUM	POTAS-SIUM DISS (MG/L)	CHLOR-IDE DISS (MG/L)	SUL-FATE DISS (MG/L)	SILICA DISS (MG/L)	FLUOR-IDE DISS (MG/L)	BROMIDE DISS (MG/L)
09306395	10/07/81	1500	1.5	32	2.9	24	170	12	0.30	--
WHITE RIVER NEAR	10/27/81	1630	1.6	30	1.8	43	180	13	0.20	--
STATE LINE	11/24/81	1600	1.5	30	1.7	30	210	13	0.30	--
	12/23/81	1430	1.7	32	1.5	24	190	11	0.30	--
	01/26/82	1400	1.7	31	1.7	28	200	15	0.30	--
	03/25/82	1200	2.0	34	1.8	38	260	12	0.30	--
	05/07/82	1500	0.80	22	1.6	6.7	66	12	0.20	--
	06/15/82	1000	0.50	15	1.2	5.5	53	12	0.20	--
	07/15/82	1000	0.70	19	1.4	9.3	87	14	0.20	--
	08/26/82	1400	1.3	28	1.8	16	150	15	0.30	--
09306430	01/28/82	1100	10	59	8.8	54	2500	9.9	0.90	--
EVACUATION CREEK	04/29/82	1000	10	59	8.1	49	2300	9.5	1.0	--
NEAR MOUTH	07/28/82	1145	8.0	57	9.2	36	1700	8.6	0.60	--
09306602 PLANT SITE WASH	09/29/82	0845	5.2	78	1.6	17	70	13	0.70	--
09306610 SOUTHAM CANYON WASH	09/29/82	1015	4.7	72	1.6	9.0	120	11	0.40	--
09306700	01/28/82	0930	1.7	31	1.6	26	190	15	0.30	0.00
WHITE RIVER BELOW	06/15/82	1100	0.50	15	1.3	6.0	55	12	0.20	--
ASPHALT WASH										

TABLE 6.4-5 (CONTINUED)

STATION NUMBER	DATE	TIME	SULFIDE TOTAL (MG/L AS S)	OXYGEN DEMAND CHEM (MG/L)	OXYGEN DEMAND, CHEM (HIGH LEVEL) (MG/L)	DIS-SOLVED ORGANIC CARBON (DOC) (MG/L)	OIL AND GREASE, TOTAL RECOV. GRAVIM. (MG/L)	AMMONIA DISS (AS N) (MG/L)	NITRITE DISS (AS N) (MG/L)	NITRATE DISS (AS N) (MG/L)
09306395	10/07/81	1500	—	—	—	—	—	—	—	—
WHITE RIVER NEAR	10/27/81	1630	—	—	—	—	—	—	—	—
STATE LINE	11/24/81	1600	—	—	—	—	—	—	—	—
	12/23/81	1430	—	—	—	—	—	—	—	—
	01/26/82	1400	—	—	—	—	—	—	—	—
	03/25/82	1200	—	—	—	—	—	—	—	—
	05/07/82	1500	—	—	—	—	—	—	—	—
	06/15/82	1000	<0.50	—	27.0	4.6	<1	0.130	<0.020	—
	07/15/82	1000	—	—	—	—	—	—	—	—
	08/26/82	1400	—	—	—	—	—	—	—	—
09306430	01/28/82	1100	—	—	—	—	—	—	—	—
EVACUATION CREEK	04/29/82	1000	<0.50	—	46.0	12	0	0.120	<0.020	—
NEAR MOUTH	07/28/82	1145	—	—	—	18	—	0.130	0.030	0.24
09306602	09/29/82	0845	<5.0	—	350.0	—	6	0.130	0.040	1.7
PLANT SITE WASH										
09306610	09/29/82	1015	<5.0	—	210.0	11	4	<0.060	<0.020	—
SOUTHAM CANYON WASH										
09306700	01/28/82	0930	0.50	—	14.0	3.3	—	0.200	—	—
WHITE RIVER BELOW	06/15/82	1100	0.60	—	44.0	9.4	<1	0.100	<0.020	—
ASPHALT WASH										

TABLE 6.4-5 (CONTINUED)

STATION NUMBER	DATE	TIME	NITRITE PLUS NITRATE DISS (AS N) (MG/L)	AMMONIA +ORGAN. NITROGN DISS. (AS N) (MG/L)	AMMONIA +ORGAN. NITROGN SUSP. (AS N) (MG/L)	AMMONIA +ORGAN. NITROGN TOTAL (AS N) (MG/L)	NITRO- GEN, ORGANIC DISS (AS N) (MG/L)	NITRO- GEN DISS (AS N) (MG/L)	PHOS- PHORUS, ORTHO DISS (AS P) (MG/L)	PHOS- PHORUS DISS. (AS P) (MG/L)
09306395	10/07/81	1500	<0.09	—	—	—	—	—	—	<0.010
WHITE RIVER NEAR	10/27/81	1630	<0.09	—	—	—	—	—	0.030	—
STATE LINE	11/24/81	1600	<0.10	—	—	—	—	—	—	<0.010
	12/23/81	1430	<0.09	—	—	—	—	—	—	0.010
	01/26/82	1400	0.18	—	—	—	—	—	0.030	—
	03/25/82	1200	<0.10	—	—	—	—	—	0.020	—
	05/07/82	1500	0.28	—	—	—	—	—	0.010	—
	06/15/82	1000	<0.10	0.70	0.20	0.90	0.57	—	0.020	0.060
	07/15/82	1000	<0.10	—	—	—	—	—	0.140	—
	08/26/82	1400	<0.10	—	—	—	—	—	0.030	—
09306430	01/28/82	1100	0.65	—	—	—	—	—	0.020	—
EVACUATION CREEK	04/29/82	1000	0.29	0.79	0.05	0.84	0.67	1.1	0.010	0.020
NEAR MOUTH	07/28/82	1145	0.27	1.3	140	140	1.2	1.6	0.020	0.080
09306602	09/29/82	0845	1.7	2.8	23	26	2.7	4.5	0.270	0.300
PLANT SITE WASH										
09306610	09/29/82	1015	0.92	1.2	0.00	1.0	—	2.1	0.180	0.200
SOUTHAM CANYON WASH										
09306700	01/28/82	0930	0.18	—	—	0.47	—	—	0.040	—
WHITE RIVER BELOW	06/15/82	1100	0.10	1.0	0.00	0.90	0.90	1.1	0.020	0.070
ASPHALT WASH										

TABLE 6.4-5 (CONTINUED)

STATION NUMBER	DATE	TIME	PHOS-PHORUS, TOTAL (AS P) (MG/L)	ALUM-INUM DISS (UG/L)	ARSENIC DISS (UG/L)	BARIUM DISS (UG/L)	BERYL-LIUM DIS-OLVED (UG/L)	BORON DISS (UG/L)	CADMIUM DISS (UG/L)	CHRO-MIUM DISS (UG/L)
09306395	10/07/81	1500	—	—	—	—	—	50	—	—
WHITE RIVER NEAR	10/27/81	1630	—	—	—	—	—	50	—	—
STATE LINE	11/24/81	1600	—	—	—	—	—	80	—	—
	12/23/81	1430	—	—	—	—	—	50	—	—
	01/26/82	1400	—	—	—	—	—	50	—	—
	03/25/82	1200	—	—	—	—	—	60	—	—
	05/07/82	1500	—	—	—	—	—	40	—	—
	06/15/82	1000	0.300	—	1	43	<1	20	<1	—
	07/15/82	1000	—	—	—	—	—	30	—	—
	08/26/82	1400	—	—	—	—	—	80	—	—
09306430	01/28/82	1100	—	—	—	—	—	1900	—	—
EVACUATION CREEK	04/29/82	1000	0.020	10	1	100	<10	1800	<1	<10
NEAR MOUTH	07/28/82	1145	1.900	—	—	—	—	510	—	—
09306602	09/29/82	0845	9.200	2200	6	99	<1	70	<1	10
PLANT SITE WASH										
09306610	09/29/82	1015	4.600	90	7	67	<1	80	<1	<10
SOUTHAM CANYON WASH										
09306700	01/28/82	0930	0.040	20	1	46	—	40	<1	<10
WHITE RIVER BELOW	06/15/82	1100	0.270	40	1	38	<1	20	<1	<10
ASPHALT WASH										

TABLE 6.4-5 (CONTINUED)

STATION NUMBER	DATE	TIME	COBALT DISS (UG/L)	COPPER DISS (UG/L)	CYANIDE TOTAL (MG/L AS CN)	IRON DISS (UG/L)	LEAD DISS (UG/L)	LITHIUM DISS (UG/L)	MAN-GANESE DISS (UG/L)	MERCURY DISS (UG/L)
09306395	10/07/81	1500	—	—	—	—	—	—	—	—
WHITE RIVER NEAR	10/27/81	1630	—	—	—	<10	—	—	<1	—
STATE LINE	11/24/81	1600	—	—	—	—	—	—	—	—
	12/23/81	1430	—	—	—	—	—	—	—	—
	01/26/82	1400	—	—	—	16	—	—	7	—
	03/25/82	1200	—	—	—	—	—	—	—	—
	05/07/82	1500	—	—	—	—	—	—	—	—
	06/15/82	1000	<3	<10	<0.01	<10	<10	12	<1	<0.10
	07/15/82	1000	—	—	—	—	—	—	—	—
	08/26/82	1400	—	—	—	—	—	—	—	—
09306430	01/28/82	1100	—	—	—	30	—	—	50	—
EVACUATION CREEK	04/29/82	1000	—	41	0.01	110	<1	130	80	<0.10
NEAR MOUTH	07/28/82	1145	—	—	—	110	—	—	20	—
09306602	09/29/82	0845	—	85	<0.01	2300	<1	14	56	<0.10
PLANT SITE WASH										
09306610	09/29/82	1015	—	80	<0.01	190	<1	16	5	0.10
SOUTHAM CANYON WASH										
09306700	01/28/82	0930	—	7	—	<10	2	19	3	<0.10
WHITE RIVER BELOW	06/15/82	1100	—	8	<0.01	40	<1	11	<1	<0.10
ASPHALT WASH										

TABLE 6.4-5 (CONTINUED)

STATION NUMBER	DATE	TIME	MOLYB-DENUM DISS (UG/L)	NICKEL DISS (UG/L)	PHENOLS (UG/L)	SELE-NIUM DISS (UG/L)	SILVER DISS (UG/L)	STRON-TIUM DISS (UG/L)	VANA-DIUM DISS (UG/L)	ZINC DISS (UG/L)
09306395	10/07/81	1500	—	—	—	—	—	—	—	—
WHITE RIVER NEAR	10/27/81	1630	—	—	—	—	—	—	—	—
STATE LINE	11/24/81	1600	—	—	—	—	—	—	—	—
	12/23/81	1430	—	—	—	—	—	—	—	—
	01/26/82	1400	—	—	—	—	—	—	—	—
	03/25/82	1200	—	—	—	—	—	—	—	—
	05/07/82	1500	—	—	—	—	—	—	—	—
	06/15/82	1000	2	—	2	1	—	330	1.8	<3
	07/15/82	1000	—	—	—	—	—	—	—	—
	08/26/82	1400	—	—	—	—	—	—	—	—
09306430	01/28/82	1100	—	—	—	—	—	—	—	—
EVACUATION CREEK	04/29/82	1000	37	1	4	3	<1	3800	<1.0	60
NEAR MOUTH	07/28/82	1145	—	—	—	—	—	—	—	—
09306602	09/29/82	0845	1	13	7	1	<1	190	23	30
PLANT SITE WASH										
09306610	09/29/82	1015	8	<1	3	2	<1	460	19	40
SOUTHAM CANYON WASH										
09306700	01/28/82	0930	<10	—	0	1	—	920	1.0	0
WHITE RIVER BELOW	06/15/82	1100	2	1	5	1	1	330	2.2	6
ASPHALT WASH										

digital recorders) or by relatively frequent field measurements. Many additional parameters were monitored on a less frequent basis by the periodic collection and laboratory analyses of water samples. Values for these parameters (Table 6.4-5) during 1982 were similar to previously collected data, which were described in detail in WRSOC baseline reports and annual progress reports covering water years 1975 through 1981. The general characterization of these 1982 data will not be repeated in this report, since it would not differ appreciably from discussions presented in the above mentioned reports. However, there are certain relationships between stations and among certain constituents that are of importance to this report, and are discussed in the following text.

Data collected at various White River stations in Utah have indicated that there is a well-defined relationship between the total dissolved solids (TDS) concentration as a calculated sum of constituents and specific conductance (EC). The data for all of these stations during the 1975 through 1979 water years define the regression equation:

$$\text{TDS in mg/l} = (0.544)(\text{EC in micromhos/cm})^{1.025}$$

This regression had a correlation coefficient of 0.977 (Lindskov and Kimball 1982). In general, the TDS concentration has been about 65% of the measured specific conductance. The ratios of TDS versus specific conductance for samples collected in 1982 varied from 56% to 71%, and averaged 64%. This relationship of TDS concentration versus specific conductance, along with the continuous specific conductance records, can be used to estimate the salinity conditions for the White River.

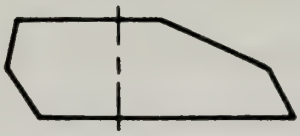
Typical distributions of major ions for the four classifications of flow sources (described in Section 6.4.1.1) have also been determined from data for the White River stations during the 1975 through 1979 water years (Lindskov

and Kimball 1982). A comparison of these typical distributions and the distributions for 1982 samples at station 6395 are shown in Figure 6.4-5. The similarities for upper basin baseflow and upper basin high flow classifications can easily be seen. The remaining three samples are not very similar to any of the four typical Stiff diagrams, because they were collected during transition periods when sources of flow were mixed. The October 7, 1981 sample was collected following regional thunderstorm runoff on October 5 and 6. It represents the mixture of lower basin baseflow with upper and lower basin high flow. The March 25, 1982 sample was collected during the recession of lower basin snowmelt runoff, so it represents a mixture of lower basin high flow and upper basin baseflow. The August 26, 1982 sample was collected during what typically would be the lower basin baseflow period. However, the heavy regional precipitation in August and September probably decreased the magnitude of irrigation diversions from the White River upstream of station 6395. Under such conditions, the proportion of irrigation return water to baseflow would also be reduced, thereby diminishing the influence of irrigation on White River water quality. The effect of this situation is reflected by the fact that the Stiff diagram for this sample is more similar to upper basin baseflow than lower basin baseflow.

Comparisons of water quality between stations 6395 and 6700 can be made for the January and June 1982 samples. The January data are very similar except for the values of specific conductance. Concentrations of TDS did not reflect corresponding differences. Comparison of the January data suggests that water quality was similar between stations during stable upper basin (winter) baseflow periods of the 1982 water year. The situation during unstable upper basin baseflow periods, such as severe freezing periods, cannot be assessed with the presently available 1982 data.

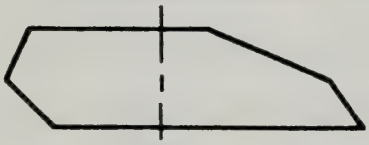
STATION NO. 09306395
1982 WATER YEAR

OCTOBER 7, 1981



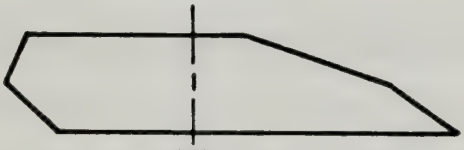
422

UPPER BASIN BASEFLOW



521

MARCH 25, 1982

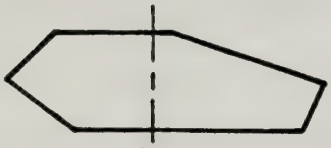


619

UPPER BASIN HIGH FLOW

250

AUGUST 26, 1982

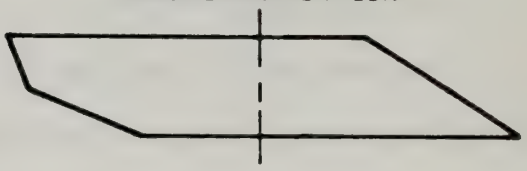


420

WHITE RIVER STATION NOS.
09306395 THROUGH 09306900
1975 – 1979 WATER YEARS

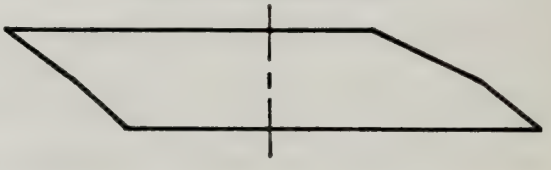
UPPER BASIN BASEFLOW

LOWER BASIN HIGH FLOW

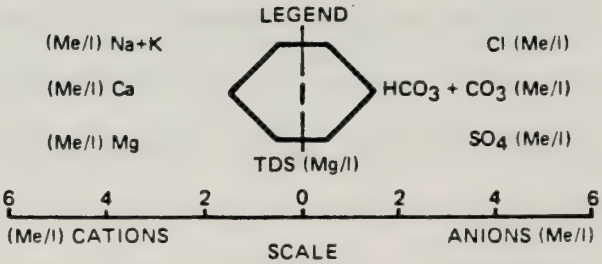


UPPER BASIN HIGH FLOW

LOWER BASIN BASEFLOW



LEGEND



DISTRIBUTION OF MAJOR IONS FOR THE WHITE RIVER

FIGURE 6.4-5

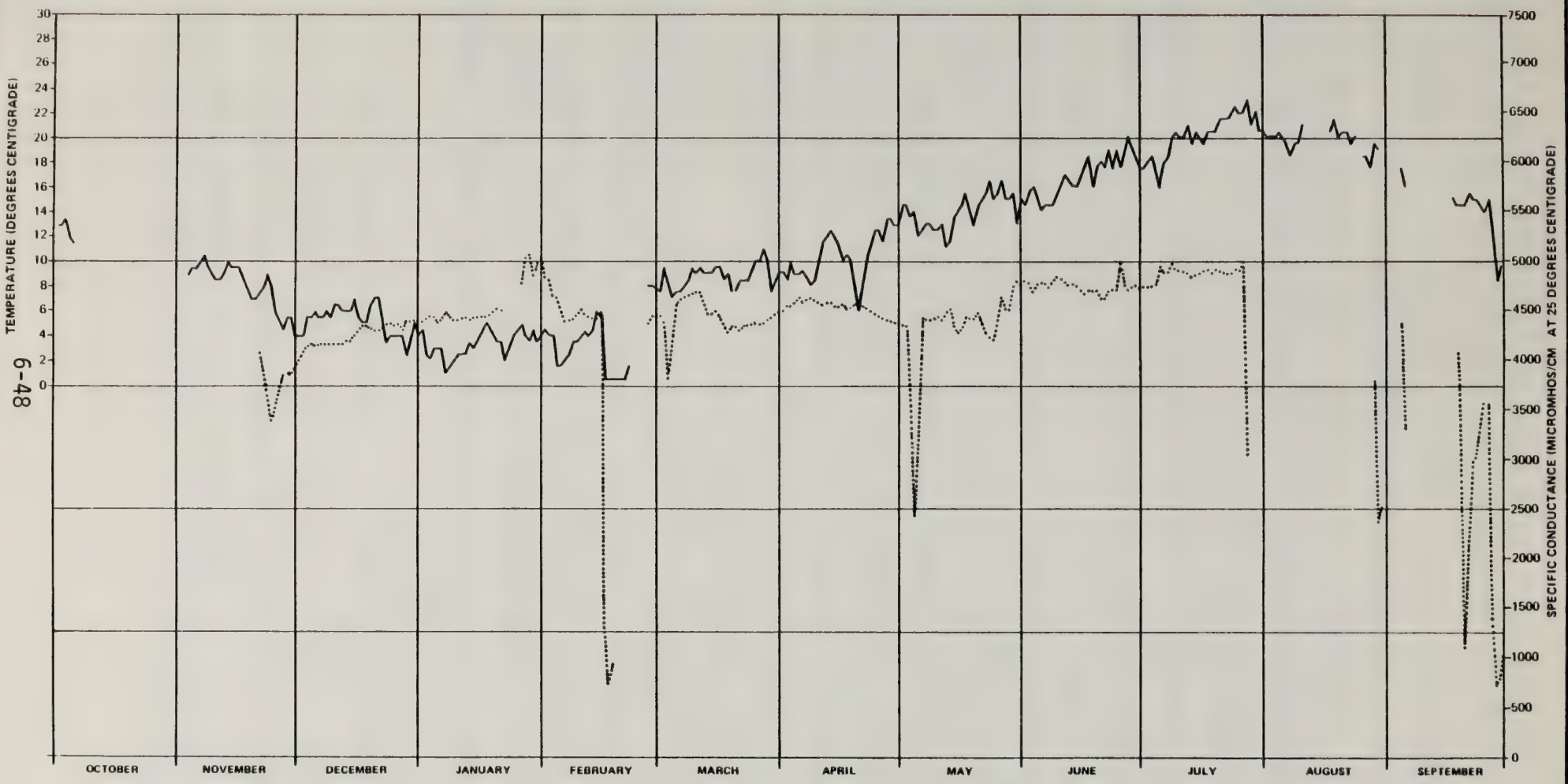
The June 15, 1982 sample data, collected during stable upper basin high flow (snowmelt runoff), identified certain differences between stations. Several constituents showed marked increases at the downstream station. These were: turbidity, suspended solids, chemical oxygen demand (COD) and dissolved organic carbon (DOC). These increases are all attributed to the natural process of bank erosion that is very active during high flow periods. Concentrations of iron, phenols and zinc showed slight increases in the downstream direction. These are not believed to be particularly significant because of the low concentrations involved. Previous data for these three constituents had not shown any consistent trend between stations during upper basin high flow. Values for selected nutrients indicated that the loading of total ammonia and organic nitrogen did not change in the downstream direction, however organic nitrogen in the suspended phase was converted to its dissolved phase.

In summary, the available White River water quality data indicate that conditions during the 1982 water year were not significantly different from conditions during previous years of record, except that the above normal regional precipitation during August and September diminished the effects of upstream irrigation typically seen during late summer baseflow. Although water quality samples were not collected during lower basin thunderstorm runoff, it is likely that general water quality conditions were similar to those seen previously, since the available continuous specific conductance data were within previous extremes. Comparisons between stations indicated that there were some water quality differences during 1982 upper basin high flow, but that they were probably due to the natural process of bank erosion. Comparisons between stations for the remaining flow regimes are limited primarily because the 1982 continuous specific conductance record at station 6395 is not yet available.

B. Evacuation Creek. The 1982 mean daily values of water temperature and specific conductance at station 6430 are shown in Figure 6.4-6. Supplemental field measurements of water temperature, specific conductance, pH and dissolved oxygen at this station are listed in Table 6.4-3.

Recorded water temperatures ranged from 0.0°C to 34.5°C and averaged 11.0°C. with 85% data recovery (for valid mean daily values). Maximum diurnal variation during the year was 21.5°C on July 12 and 19. These values, as well as the 1982 seasonal variations, are similar to previous years of record. The previously recorded maximum water temperature was 34.0°C. The diurnal variations of water temperature for Evacuation Creek closely follow air temperature variations through most of the year. Ground water discharges to the streambed immediately upstream of the station provide a slight warming influence during winter periods. Also, snowmelt runoff usually decreases water temperatures to near 0°C for short periods of time.

Recorded specific conductance ranged from 520 to 10,000 micromhos/cm during the year, with 70% data recovery (for valid mean daily values). The previously recorded maximum value of specific conductance was 9,900 micromhos/cm. The missing record in 1982 and previous years was generally during and following high flow periods, and was caused by silt deposition on the probe. Thus, the daily values records are primarily composed of values for stable low flow periods. Annual minimum values have consistently occurred during high flow periods, and are due to dilution of baseflow. Annual maximum values have also consistently occurred during high flow periods, but are due to the initial dissolution and flushing of evaporite salts that accumulate in the channel streambeds and soil and rock surfaces. Rapidly changing streamflow conditions cause wide daily variations of specific conductance.



LEGEND

TEMPERATURE

SPECIFIC CONDUCTANCE

EVACUATION CREEK NEAR MOUTH, NEAR WATSON, UTAH (STA. NO. 09306430)

MEAN DAILY TEMPERATURE AND SPECIFIC CONDUCTANCE

OCTOBER 1981 – SEPTEMBER 1982

FIGURE 6.4.6

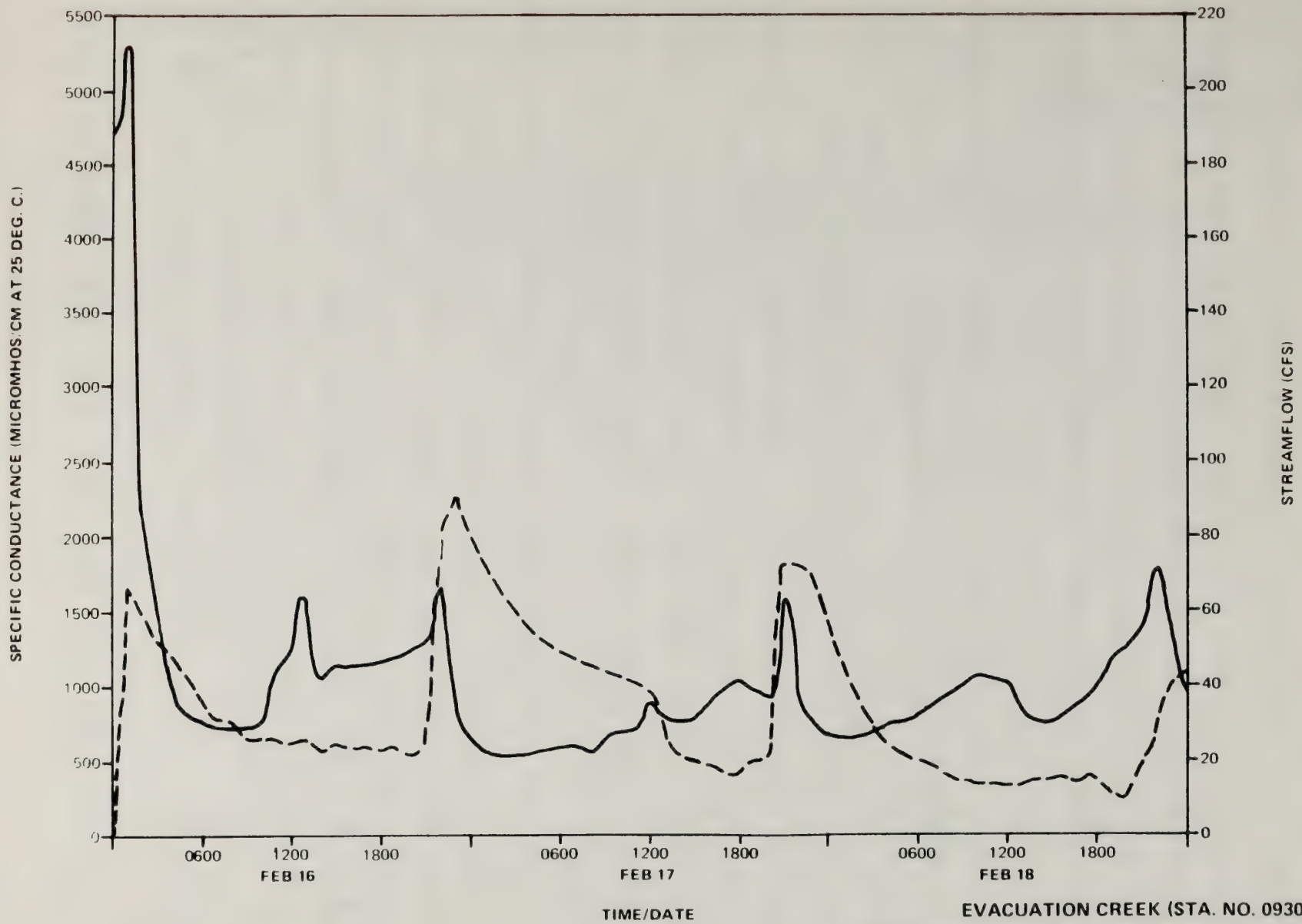
An example of the relationship of streamflow and specific conductance during 1982 snowmelt runoff is shown in Figure 6.4-7. During each day there was a short-term increase in specific conductance coinciding with the initial rapid rise in streamflow. As flow continued to remain high, the specific conductance decreased to daily minimum levels. During the flow recession, specific conductance slowly increased.

Another example of this relationship for a small runoff event caused by rainfall on May 3, 1982 is shown in Figure 6.4-8. There was a large increase in specific conductance during the initial rise in streamflow. As the flow increased further, the specific conductance decreased to its daily minimum. When streamflow decreased, the specific conductance slowly increased, but did not return to baseflow levels (4,000 to 5,000 micromhos/cm) until May 5.

Several values of pH during 1982 were below the minimum value during the previous period of record (7.0 units). These occurred mostly during low flow from May through July; however, the lowest value (6.0 units) occurred on July 28 during the recession of a flash flood.

Dissolved oxygen concentrations were variable as in previous years, and ranged from 5.8 mg/l to 11.2 mg/l. Concentrations generally followed an inverse relationship with water temperatures, but were probably decreased at times by the influences of nearby ground water discharges during low flow and by suspended solids (sediment and organic material) during and immediately following high flow periods.

Laboratory water quality data for station 6430 are listed in Table 6.4-5. The 1982 data were within observed ranges of previously collected data, with a few exceptions. The nature of Evacuation Creek water quality has been described in previous WRSOC baseline and annual progress reports; therefore, this discussion will concentrate on values outside of previously observed



LEGEND

STREAMFLOW

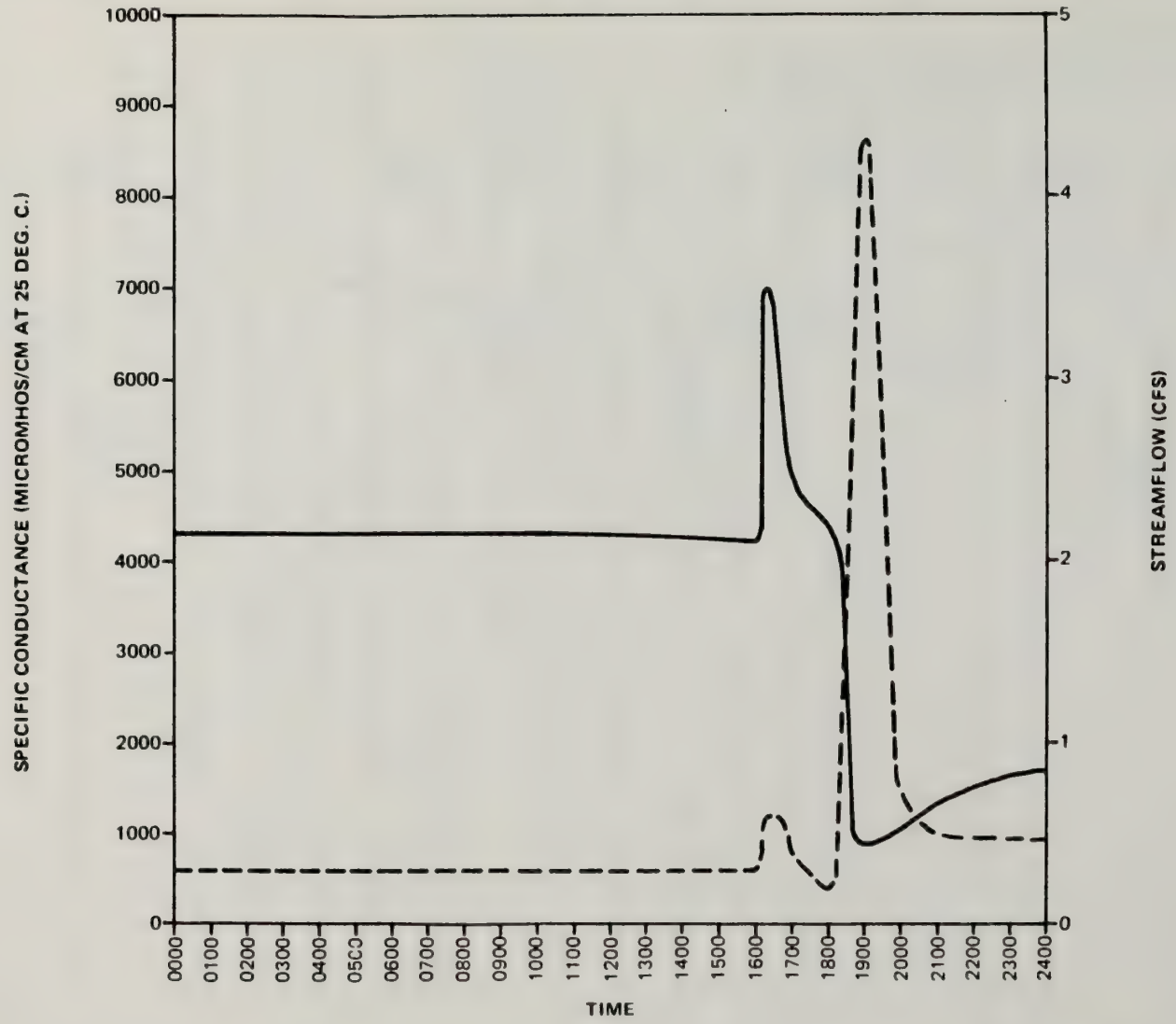
SPECIFIC CONDUCTANCE

EVACUATION CREEK (STA. NO. 09306430)

STREAMFLOW VS. SPECIFIC CONDUCTANCE

FEBRUARY 16 – 18, 1982

FIGURE 6.4-7



LEGEND

STREAMFLOW

SPECIFIC CONDUCTANCE

EVACUATION CREEK (STA. NO. 09306430)

STREAMFLOW VS. SPECIFIC CONDUCTANCE

MAY 3, 1982

FIGURE 6.4-8

ranges. The values of lab alkalinity (593 mg/l) and total ammonia plus organic nitrogen (140 mg/l) for the July 28 sample were well above previously observed maximum values (460 mg/l and 30 mg/l, respectively). This sample was collected immediately following the recession of a relatively large flash flood, and the suspended solids concentration (61,800 mg/l) was very high considering the amount of flow at the time (0.23 cfs). Flash floods in this watershed typically transport a great deal of organic material with surface runoff. This probably caused a temporary loading of nitrogen compounds to the stream system. It is not known at this time whether the effects of the flash flood also led to the increased lab alkalinity and decreased field pH value for this sample.

In summary, water quality for Evacuation Creek during the 1982 water year was generally similar to previous years. A few parameters (water temperature, specific conductance, pH, lab alkalinity, and total ammonia plus organic nitrogen) did exceed previously observed ranges during the year. There were only minor project-related disturbances in this watershed; therefore, it is likely that observed differences from previous records were caused by the hydrologic system's response to natural variations in climatic conditions or, possibly, some or all of the differences could have been due to nonproject-related activities in the Evacuation Creek watershed upstream of the tracts.

C. Dry Washes. The observed temperature ranges during 1982 from continuous recorders at stations 6602 and 6610 were 1.0°C to 29.0°C and 6.0°C to 29.0°C, respectively. Both of these records are largely incomplete due to silt deposition on the probes during the periods of flow.

The observed specific conductance ranges during the year from continuous recorders at stations 6602 and 6610 were 110 to 492 and 56 to 576 micromhos/cm, respectively. Again, both records are largely incomplete for

similar reasons. The 1982 maximum value for station 6610 is within previously observed ranges. Minimum values for 1982 and previous years are considered questionable because it is very difficult to determine when silt is affecting the probe reading. The 1982 specific conductance records for these two stations are somewhat similar for comparable periods of flow.

Field water quality measurements during the year for stations 6602 and 6610 are shown in Table 6.4-4. Laboratory analyses are listed in Table 6.4-5. The USGS was unable to make any field measurements or collect any samples at station 6625 during the year.

Water quality results for station 6610 during 1982 are similar to previously collected data, with one exception. The field pH value for September 29 (7.2 units) is slightly below the previously observed range (7.9 to 8.8 units) from four measurements.

Comparison of the September 29 data for stations 6602 and 6610 indicates that there were some differences in the water quality of runoff from these two watersheds. Specific conductance and the TDS concentration were slightly lower at station 6602. This is not believed to be particularly significant because it is known that specific conductance and TDS will fluctuate over a fairly wide range during a single flow event. The distributions of major ions were generally similar for both stations. In both cases, sodium was the dominant cation and bicarbonate was the dominant anion.

Values for all of the dissolved nutrients (nitrogen and phosphorus compounds) were slightly higher at station 6602 than at station 6610. Values for COD, total ammonia plus organic nitrogen, and total phosphorus were much higher at station 6602 than at station 6610; however, they are not greater than respective maximum values at station 6610 during the period of record. The differences in these three constituents between stations are probably

related to construction activities within the Plant Site Wash drainage. Suspended sediment data indicated that earthwork activities probably caused an increase in the amount of fine-grained material in Plant Site Wash runoff. Compounds used in construction such as explosives, are also a potential source for increased nitrogen compound concentrations.

Values for some of the dissolved trace materials showed notable differences between stations 6602 and 6610. These included aluminum, iron, manganese, molybdenum, nickel and strontium. The concentrations of dissolved strontium (190 ug/l) and molybdenum (1 ug/l) at station 6602 were less than minimum values for the period of record at station 6610 (200 ug/l and 3 ug/l, respectively). The concentrations of dissolved aluminum and manganese at station 6602 were greater than those at station 6610 on September 29, but were within observed ranges for previously collected data at station 6610. The concentrations of dissolved iron (2200 ug/l) and nickel (13 ug/l) at station 6602 were greater than maximum values for the period of record at station 6610 (1000 ug/l and < 2 ug/l, respectively). It is believed that the differences in concentrations of dissolved iron and nickel are of significance; however, it is not known whether they are due to natural variations in water quality between watersheds, or were caused by project activities in the Plant Site Wash drainage.

In summary, the water quality data collected at station 6610 during the 1982 water year indicated that conditions were similar to previous years. This was to be expected since no significant disturbance has occurred in the Southam Canyon Wash watershed to date. No water quality data were collected at station 6602 prior to 1982, therefore comparisons to earlier records cannot be made. (Baseline monitoring was initiated at station 6602 during the 1981 water year; however, there were no flow events during that year.) Comparison

of 1982 data for stations 6602 and 6610 indicates that the general characteristics of water quality and major ion distributions were similar. In contrast, nutrient levels were greater at station 6602, especially in the suspended phase. This is attributed to construction activities in Plant Site Wash. It is not known whether the increased nutrient levels were caused simply by disturbance of surface materials or by compounds (such as explosives) used in construction activities. In any case, the observed nutrient levels at station 6602 were not significantly greater than respective maximum values observed at station 6610 during the entire baseline period. Values of several trace materials also illustrated notable differences between stations. Only the concentrations of dissolved iron and nickel are believed to be of significance, because the values for station 6602 are greater than respective maximum values for the period of record at station 6610. The cause(s) for the differences in these two constituents are not known at the present time.

6.4.2 Bedrock Aquifers

6.4.2.1 Birds Nest Zone Ground water conditions and analyses for the three continuously monitored wells (P-1, P-2 Lower, and P-3) are described individually below. Ground water conditions and analyses of the seven other Birds Nest Zone wells (G-wells), which have been monitored on a semi-annual or contingency basis, are described collectively following the P-well discussion. This sub-section concludes with a general discussion of recent ground water level conditions for all Birds Nest Zone wells.

The discussions are limited to water levels only. No ground water quality data were collected for these wells during the 1982 water year.

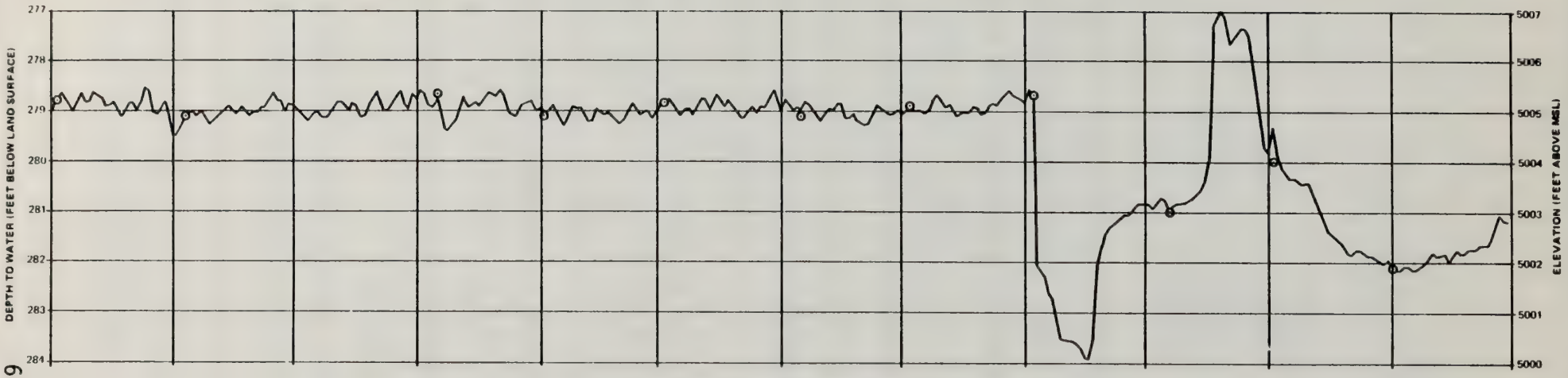
A. Well P-1. The maximum, minimum and mean annual depths to water and the corresponding static water level elevations observed during the 1982 water year at well P-1 are tabulated below.

WELL P-1
ANNUAL EXTREME AND MEAN STATIC WATER LEVELS
(Land Surface Elevation: 5,284.0 feet)

	Elevation (ft)	Depth (ft)	Date
Low	5,000.1	283.94	6/16/82
High	5,007.0	276.98	7/19/82
Mean	5,004.3	279.67	

Up to June 1982, the mean daily depth to water was about 279 feet, and fluctuated between about 278.5 and 279.5 feet. These observed mean daily water levels and range of fluctuations were very similar to those observed during the 1981 water year and previous periods. However, beginning June 2, the water level declined rapidly and by June 16 had reached the maximum depth for the year of 283.94 feet, representing a decline of about 5.4 feet over 14 days. Most of this decline (a net decrease of three feet) occurred during a two-day period from June 2 to June 4. Static water levels then recovered rapidly, rising about seven feet between June 16 and July 19 to the minimum depth for the year of 276.98 feet. The majority of the seven-foot increase (the extreme annual fluctuation measured at P-1), occurred over two very brief recovery periods. After the July 19 peak, the static water level again declined rapidly below previously observed levels, from which it is apparently slowly recovering. A continuous hydrograph of static water levels at well P-1 for the 1982 water year is shown in Figure 6.4-9.

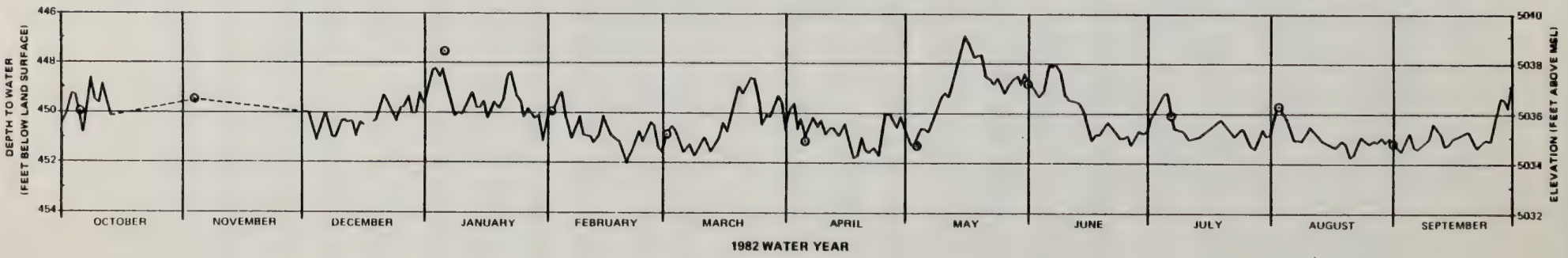
The rapid shifts in static water level are not fully understood but the phenomenon is apparently localized near P-1 since other wells with continuous water level recorders (P-2 Lower and P-3) do not directly reflect this condition. Although the mechanisms controlling these static water level fluctuations are not clear, it is possible that they are related to surface



MEAN DAILY STATIC WATER LEVEL

MONITOR WELL P-1

LAND SURFACE ELEVATION = 5284.0



MEAN DAILY STATIC WATER LEVEL

MONITOR WELL P-3

LAND SURFACE ELEVATION = 5486.0

LEGEND

------ PERIOD OF POOR DATA RECOVERY, LINE SHOWS ESTIMATED VALUE

NOTE: ⊙ ARE MANUAL MEASUREMENTS BY ELECTRIC PROBE

FIGURE 6.4-9

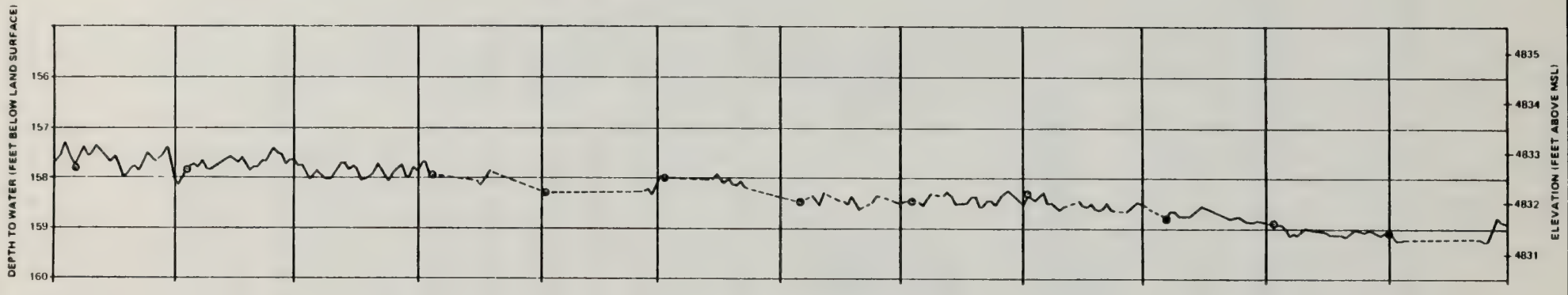
excavation blasting occurring near the P-1 site at the approximate time the shifts occurred. Based on equipment checks and manual measurements, the recorded values are believed to represent actual static water level fluctuations and are not caused by recorder malfunction.

B. Well P-2 Lower. The maximum, minimum and mean annual depths to water and corresponding static water level elevations observed during the 1982 water year at well P-2 Lower are tabulated below.

WELL P-2 LOWER
ANNUAL EXTREME AND MEAN STATIC WATER LEVELS
(Land Surface Elevation: 4,990.5 feet)

	Elevation (ft)	Depth (ft)	Date
Low	4,831.3	159.24	9/6/82
High	4,833.2	157.34	11/25/81
Mean	4,832.2	158.32	

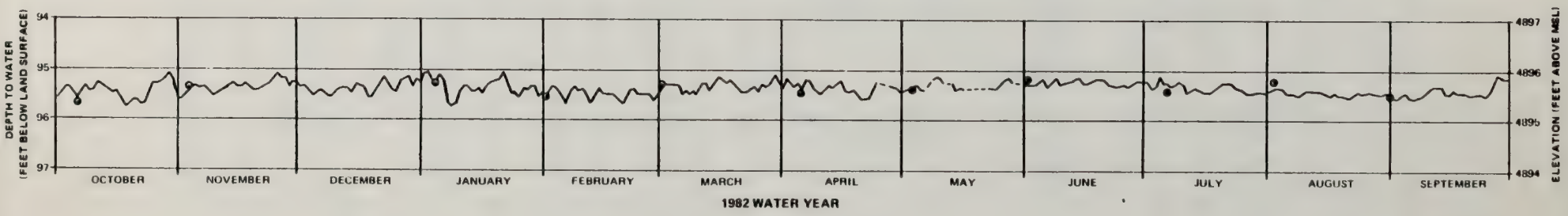
The extreme annual fluctuation was 1.90 feet and occurred between November 25, 1981 (highest water level) and September 6, 1982 (lowest water level). A continuous hydrograph of static water levels at well P-2 Lower for the 1982 water year is shown in Figure 6.4-10. While short-term fluctuations in water level (about 0.5 feet), were normal compared to previous years a net decline in water level of about 1.5 feet occurred over the 1982 water year. This is a continuation of a trend involving declining water levels at this well that has been observed since mid-1980. The net decline in water level occurring since that time (about two and one-half years) is now about six feet. Water levels are now at their lowest point for the entire period of record and, since the lowest values were recorded in September 1982, the trend is expected to continue into the 1983 water year.



MEAN DAILY STATIC WATER LEVEL

MONITOR WELL P-2 LOWER

LAND SURFACE ELEVATION = 4990.5



MEAN DAILY STATIC WATER LEVEL

MONITOR WELL P-2 UPPER

LAND SURFACE ELEVATION = 4991.0

LEGEND

----- PERIOD OF POOR DATA RECOVERY, LINE SHOWS ESTIMATED VALUE

NOTE: ⊙ ARE MANUAL MEASUREMENTS BY ELECTRIC PROBE

FIGURE 6.4-10

The long-term decline in static water levels at P-2 Lower is probably related to a withdrawal of Birds Nest Zone ground water to the north or northwest of the well site. This subject is discussed in detail in the summary for all Birds Nest Zone wells.

C. Well P-3. The maximum, minimum and mean annual depths to water and corresponding static water level elevations observed during 1982 water year at well P-3 are tabulated below.

WELL P-3
ANNUAL EXTREME AND MEAN STATIC WATER LEVELS
(Land Surface Elevation: 5,486.0 feet)

	Elevation (ft)	Depth (ft)	Date
Low	5,034.0	451.96	2/20/82
High	5,039.1	446.85	5/15/82
Mean	5,035.7	450.26	

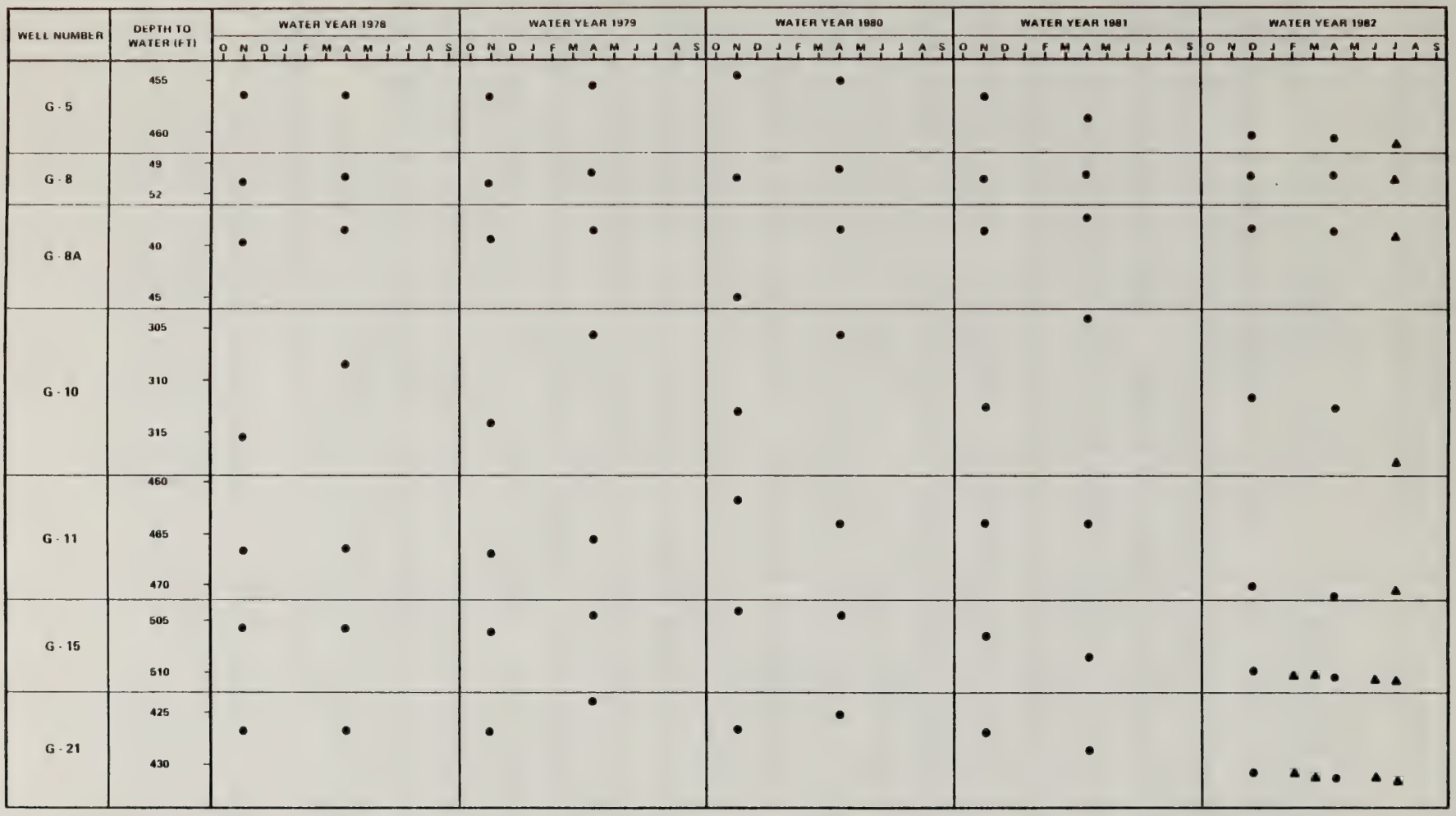
The extreme annual fluctuation was 5.11 feet and occurred between February 20, 1982 (lowest water level) and May 15, 1982 (highest water level). A continuous hydrograph of static water levels at well P-3 for the 1982 water year is shown in Figure 6.4-9. Water level fluctuations and mean water level were within normal ranges compared with the 1981 water year and earlier periods.

D. G-Wells. In general, water level measurements at wells G-5, G-8, G-8A, G-10, G-11, G-15 and G-21 indicated variable declines during the 1982 water year. Only one measurement was taken at well G-14, which was added to the monitoring program late in the year. The static water level measurements taken at the G-wells during the 1982 water year are summarized in Table 6.4-6.

The largest annual static water level declines (April 1981 versus April 1982, see Figure 6.4-11) among this group of wells occurred at well G-10,

TABLE 6.4-6
BEDROCK AQUIFER MONITORING WELLS
STATIC WATER LEVELS
OCTOBER 1981 TO SEPTEMBER 1982

LOCAL IDENTIFIER	DATE	TIME	DEPTH OF WELL (FEET)	ELEVATION OF LAND SURFACE DATUM (FEET)	WATER LEVEL (FEET BELOW LSD)	ELEVATION OF STATIC WATER LEVEL (FEET)
G-10	12/06/81	1100	400	5364.0	311.65	5052.35
	04/26/82	1250	400	5364.0	312.60	5051.40
	07/07/82	0930	400	5364.0	317.82	5046.18
G-11	12/06/81	1010	500	5375.0	469.90	4905.10
	04/26/82	1200	500	5375.0	470.92	4904.08
	07/07/82	1100	500	5375.0	470.06	4904.94
G-14	07/07/82	1220	90	5270.0	38.70	5231.30
G-15	12/06/81	0945	627	5343.0	510.00	4833.00
	02/02/82	1130	627	5343.0	510.32	4832.68
	03/23/82	1230	627	5343.0	510.35	4832.65
	04/26/82	1130	627	5343.0	510.51	4832.49
	06/14/82	1100	627	5343.0	510.80	4832.20
	07/07/82	1000	627	5343.0	510.89	4832.11
G-21	12/06/81	0920	612	5262.0	430.90	4831.10
	02/02/82	1100	612	5262.0	430.95	4831.05
	03/23/82	1200	612	5262.0	431.09	4830.91
	04/26/82	1050	612	5262.0	431.22	4830.78
	06/14/82	1020	612	5262.0	431.20	4830.80
	07/07/82	1015	612	5262.0	431.50	4830.50
G-5	12/06/81	1025	620	5292.0	460.50	4831.50
	04/26/82	1220	620	5292.0	460.82	4831.18
	07/07/82	1120	620	5292.0	461.10	4830.90
G-8	12/06/81	1150	127	5095.5	50.35	5045.15
	04/26/82	1400	127	5095.5	50.27	5045.23
	07/07/82	1245	127	5095.5	50.71	5044.79
G-8A	12/06/81	1140	100	5095.0	38.30	5056.70
	04/26/82	1355	100	5095.0	38.50	5056.50
	07/07/82	1240	100	5095.0	39.03	5055.97
P-4	12/06/81	1130	400	5718.5	262.90	5455.60
	04/26/82	1335	400	5718.5	262.76	5455.74



LEGEND

● SCHEDULED SEMI ANNUAL WATER LEVEL MEASUREMENTS

▲ SUPPLEMENTAL WATER LEVEL MEASUREMENTS

STATIC WATER LEVELS OF SELECTED BIRDS NEST ZONE MONITORING WELLS

WATER YEARS 1978 – 1982

FIGURE 6.4-11

which dropped 8.1 feet, and at well G-11, which dropped 7.0 feet. The decline in static water level at the remaining wells ranged from 0.2 feet at well G-8 to 2.5 feet at well G-21.

During the period April 26 to July 7, 1982, most of the these G-wells exhibited a small decline in static water level ranging from 0.3 feet to 0.5 feet. However, static water levels at well G-10 declined 5.2 feet during this period and rose by 0.3 foot at well G-11. Surface excavation blasting was occurring in the vicinity of wells G-10 and G-11 during this period. It is possible that water levels at these two wells may have been affected in a manner similar to that for well P-1. However, the two available instantaneous measurements (April 26 and July 7) for each well are not adequate for verification of this possibility.

Figure 6.4-11 presents a comparison of static water levels occurring at similar times during the past several water years at the G-wells. The figure indicates that water levels for most of the G-wells are presently five to seven feet below comparable historic water levels, and that notable water level declines have occurred during the 1981 and 1982 water years. Wells G-8 and G-8A are exceptions, since their water levels have remained relatively stable during water years 1978-1982. In each of four cases (wells G-5, G-11, G-15 and G-21), observed static water levels are presently (July 7, 1982) at their lowest measured values since the 1977 water year. None of the Birds Nest Zone wells have been pumped since the 1976 water year.

Unlike the previous discussions of water level conditions derived from the continuously monitored P-wells, the above descriptions of water level conditions for the G-wells are based on widely-spaced measurements and are therefore limited in their representativeness of detailed short-term ground water conditions.

E. Summary of Water Level Fluctuations for Birds Nest Zone Wells. The most notable observation in the Birds Nest Zone has been the dramatic shifts in static water level that occurred at well P-1. As mentioned earlier, the phenomenon is not fully understood but may be related to surface excavation blasting near the well site.

Water levels at wells G-8, G-8A and P-3 have remained relatively stable throughout the 1982 water year. At well P-2 Lower, water levels have continued a steady, long-term decline which began in mid-1980. Water levels at other wells also began to illustrate gradual declines for comparable periods after mid-1980. Water levels at wells G-5, G-15 and G-21 declined during the 1981 and 1982 water years. In contrast, water levels at wells G-10 and G-11 declined only during the 1982 water year. Taken together, the data suggest that a cone of depression has spread from the northwest to the southeast across the tracts. This direction is up- gradient in comparison to the piezometric contours of the Birds Nest Zone. Those wells which have the highest piezometric surface (in terms of elevation), namely wells P-3, G-8 and G-8A, have shown little or no decline in static water level up to the present time.

The cause(s) for the recent general decline in Birds Nest Zone water levels are not fully understood at this time. However, it is probable that the observations (excluding conditions at well P-1) are explainable in terms of increased discharge from the Birds Nest Zone to the north or northwest of the tracts. Necessary information to verify or discount such a relationship is not presently available.

In any case, the decline in water levels is not believed to represent any significant depletion in aquifer storage below the tracts since most of the effect has occurred in the confined portions of the Birds Nest Zone (well G-15 being the one exception). The principal effect of the declines is a

redistribution of piezometric contours in the aquifer, which will influence to a small degree the direction and rate of ground water flow below the tracts.

6.4.2.2 Upper Aquifer. The maximum, minimum and mean annual depths to water and the corresponding static water level elevations observed during the 1982 water year at well P-2 Upper are tabulated below.

WELL P-2 UPPER
ANNUAL EXTREME AND MEAN STATIC WATER LEVELS
(Land Surface Elevation: 4,991.0 feet)

	Elevation (ft)	Depth (ft)	Date
Low	4,895.2	95.77	1/08/82
High	4,896.0	95.01	10/29/81
Mean	4,895.6	95.37	

The extreme annual fluctuation was 0.76 feet and occurred between October 29, 1981 (highest water level) and January 8, 1982 (lowest water level). A continuous hydrograph of static water levels at well P-2 Upper for the 1982 water year is shown in Figure 6.4-10. The mean water levels and range of fluctuation were very similar to those observed during the 1981 water year and previous periods.

6.4.2.3 Douglas Creek Aquifer. The semi-annual water level measurements taken at well P-4 during the 1978 through the 1982 water years are tabulated in Table 6.4-7. The table indicates that no significant change in well P-4 water levels has occurred in recent years. The Douglas Creek Aquifer below the tracts is therefore considered to presently have an established long-term stability with respect to static water level.

TABLE 6.4-7

WELL P-4
SUMMARY OF SEMI-ANNUAL MEASUREMENTS
OF DEPTH TO WATER (FEET BELOW GROUND SURFACE)
WATER YEARS 1978-1982

Water Year 1978	Date	Water Year 1979	Date	Water Year 1980	Date	Water Year 1981	Date	Water Year 1982	Date
263.0	11/7/77	263.2	11/14/78	262.8	11/19/79	262.3	11/5/80	262.9	12/06/81
262.7	4/13/78	262.7	4/23/79	262.0	4/21/80	262.4	4/29/81	262.8	4/26/82

6.4.3 Alluvial Ground Water

6.4.3.1 Water Levels Water level data collected at the three alluvial ground water monitoring wells (AG-3-1, AG-3-3 and AG-6-1) are tabulated in Table 6.4-8. Annual ranges in water levels at all three wells were similar to most of the previous years of record. The highest annual water levels during the period of record at all three wells appear to coincide with the magnitude and timing of upper basin snowmelt runoff for the White River. Since each well is within a few hundred feet of the White River, this suggests that there is a direct recharge relationship between the alluvial water bearing zones and the river.

Well AG-6-1 is located within the channel bed of Southam Canyon Wash. Water level data for this well during the period of record have not reflected any noticeable recharge to the alluvial water bearing zone following periods of runoff from Southam Canyon Wash. This is probably due to the fact that runoff typically lasts only a few minutes or hours.

6.4.3.2 Water Quality Field water quality data collected at the three alluvial groundwater monitoring wells are tabulated below.

Well Number	Date	Water Temp. (°C)	Specific Conductance (umhos/cm)	pH (units)
AG-3-1	12/7/81	11.1	3,000	7.6
	4/27/82	9.8	3,000	8.2
AG-3-3	12/7/81	11.7	1,650	6.8
	4/27/82	10.0	1,750	8.0
AG-6-1	12/7/81	12.6	1,300	6.8
	4/30/82	12.0	1,290	8.0
	5/21/82	13.5	1,250	8.4

Water temperature at all three wells show no significant change from earlier baseline values.

TABLE 6.4-8
ALLUVIAL MONITORING WELLS
STATIC WATER LEVELS
OCTOBER 1981 TO SEPTEMBER 1982

STATION NAME	DATE	TIME	DEPTH OF WELL (FEET)	ELEVATION OF LAND SURFACE DATUM (FEET)	WATER LEVEL (FEET BELOW LSD)	ELEVATION OF STATIC WATER LEVEL (FEET)
AG-3-1 LOWER	12/07/81	1015	38	4880.0	9.60	4870.40
	04/27/82	1305	38	4880.0	9.00	4871.00
	06/15/82	1150	38	4880.0	6.90	4873.10
AG-3-3 UPPER	12/07/81	1120	18	4880.0	9.25	4870.75
	04/27/82	1300	18	4880.0	8.60	4871.40
	06/15/82	1145	18	4880.0	6.50	4873.50
AG-6-1 LOWER	12/07/81	1125	27	4920.0	15.30	4904.70
	04/30/82	0845	27	4920.0	14.90	4905.10
	05/21/82	1025	27	4920.0	14.10	4905.90
	06/18/82	1000	27	4920.0	13.43	4906.57

Specific conductance at wells AG-3-1 and AG-3-3 decreased by approximately 1,200 and 1,000 micromhos/cm, respectively, between the 1979 water year and the 1981 water year, and then remained at similar levels during the 1982 water year. At well AG-6-1, specific conductance decreased from a range of 6,180 to 7,250 micromhos/cm during the 1976 water year to a range of 1,300 to 1,900 micromhos/cm during the 1979 year, followed by a smaller decline to a range of 1,250 to 1,300 micromhos/cm during the 1982 water year. The declines in specific conductance at these three wells do not correspond exactly, in regards to timing, with the occurrences of above normal upper basin snowmelt runoff. Although increased recharge from the White River would probably decrease the specific conductance of alluvial water, the effects are apparently not seen immediately, or other unknown factors may also be involved.

A water quality sample was collected from well AG-6-1 in May 1982 in order to define current water quality characteristics for this well, since recent specific conductance measurements were somewhat lower than in September 1979 when the previous water quality sample was collected. The May 1982 laboratory analysis from well AG-6-1 is presented in Table 6.4-9 A Piper diagram, depicting changes in water quality at AG-6-1 through the entire period of record is presented in Figure 6.4-12. The Piper diagram illustrates that, with respect to major ions, water quality has changed progressively since 1976 from a $Ca+Mg+Na/SO_4$ composition through a series of intermediate stages to a Na/HCO_3+SO_4 composition. In comparison to the September 1979 data, there have been notable decreases for specific conductance, TDS and most of the major ions, as expected. Several dissolved trace metals (boron, copper, iron, manganese, zinc and strontium) also showed notable decreases. Certain nutrients (dissolved nitrite plus nitrate, total ammonia plus organic nitrogen, and total phosphorus) increased notably. The remaining constituent values were similar to the previous data.

TABLE 6.4-9

WELL AG-6-1
WATER QUALITY DATA
MAY 21, 1982

DATE	TIME	DEPTH OF SAMPLE (FT FM SUR-FACE)	WATER TEMPER-ATURE (DEG C)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	PH FIELD (UNITS)	OXYGEN DEMAND, CHEM (HIGH LEVEL) (MG/L)	COLOR (PCU)	TURBI-DITY (NTU)	SUS-PENDED SOLIDS, RESIDUE @ 105 C (MG/L)	TOTAL DISS SOLIDS @180 C (TDS) (MG/L)	TOTAL DISS SOLIDS (SUM) (MG/L)
05/21/82	1025	18	13.5	1250	8.4	34.0	60	660	122	785	801

DATE	TIME	ALKALI-NITY, LAB (MG/L AS CACO3)	HARD-NESS TOTAL (AS CACO3) (MG/L)	NONCARB HARD-NESS LAB (MG/L CACO3)	CALCIUM DISS (MG/L)	MAGNE-SIUM DISS (MG/L)	SODIUM DISS (MG/L)	SODIUM ADSORP-TION RATIO (SAR)	PERCENT SODIUM	POTAS-SIUM DISS (MG/L)	CHLOR-IDE DISS (MG/L)
05/21/82	1025	300	230	0.00	45	28	190	6.1	64	1.9	42

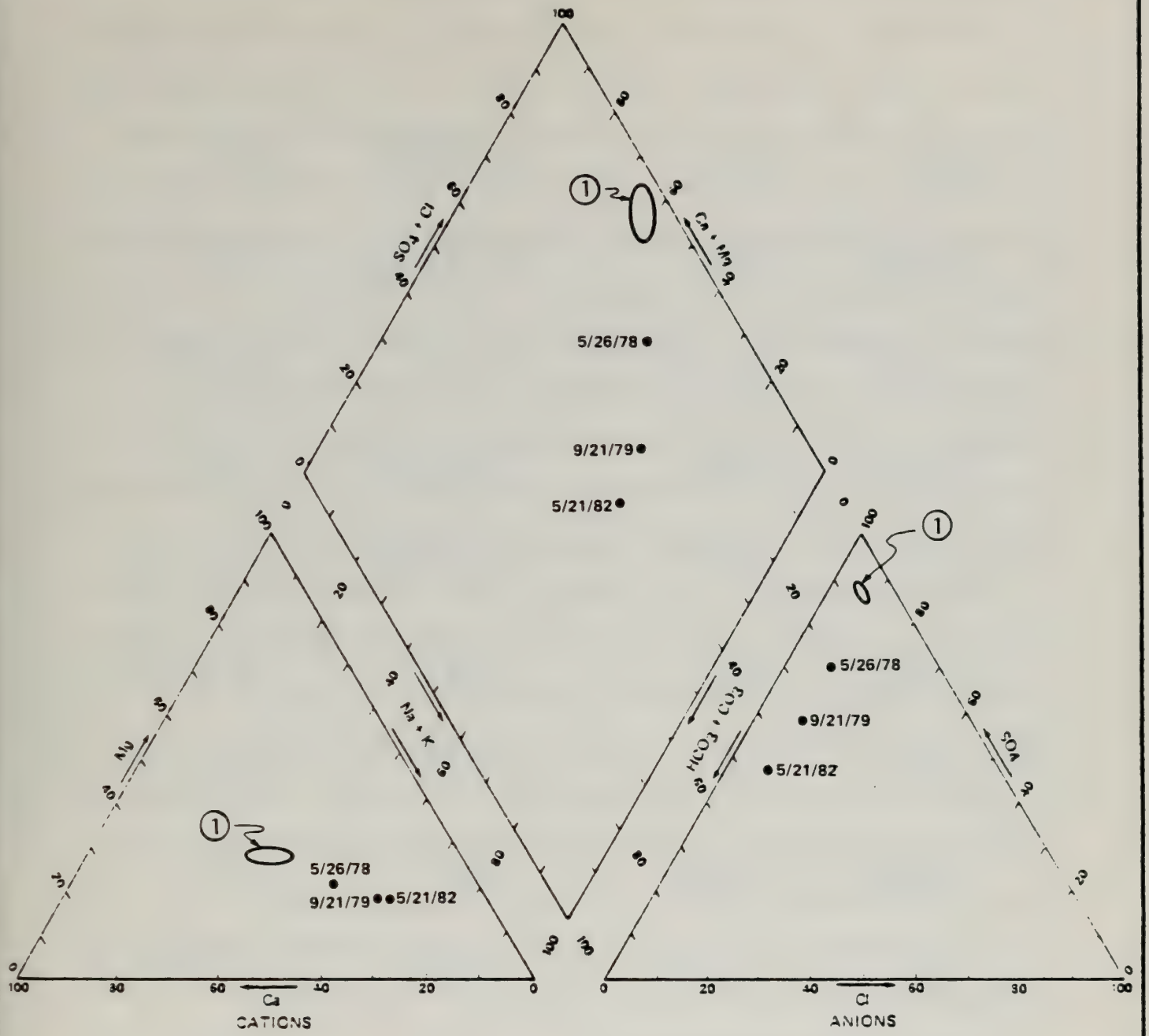
DATE	TIME	SUL-FATE DISS (MG/L)	SILICA DISS (MG/L)	FLUOR-IDE DISS (MG/L)	SULFIDE TOTAL (MG/L AS S)	DIS-SOLVED ORGANIC CARBON (DOC) (MG/L)	OIL AND GREASE, TOTAL RECOV. GRAVIM. (MG/L)	AMMONIA DISS (AS N) (MG/L)	NITRITE DISS (AS N) (MG/L)	NITRITE PLUS NITRATE DISS (AS N) (MG/L)	AMMONIA +ORGAN. NITROGN DISS. (AS N) (MG/L)
05/21/82	1025	290	21	0.40	<0.50	8.1	0	<0.060	<0.020	0.23	0.80

TABLE 6.4-9 (CONTINUED)

DATE	TIME	AMMONIA +ORGAN. NITROGN SUSP. (AS N) (MG/L)	AMMONIA +ORGAN. NITROGN TOTAL (AS N) (MG/L)	NITRO-GEN DISS (AS N) (MG/L)	PHOS-PHORUS, ORTHO DISS (AS P) (MG/L)	PHOS-PHORUS DISS. (AS P) (MG/L)	PHOS-PHORUS, TOTAL (AS P) (MG/L)	ALUM-INUM DISS (UG/L)	ARSENIC DISS (UG/L)	BARIUM DISS (UG/L)	BERYL-LIUM DIS-OLVED (UG/L)
05/21/82	1025	0.60	1.4	1.0	0.050	0.180	0.980	10	5	38	<3

DATE	TIME	BORON DISS (UG/L)	CADMIUM DISS (UG/L)	CHRO-MIUM DISS (UG/L)	COPPER DISS (UG/L)	CYANIDE TOTAL (MG/L AS CN)	IRON DISS (UG/L)	LEAD DISS (UG/L)	LITHIUM DISS (UG/L)	MAN-GANESE DISS (UG/L)	MERCURY DISS (UG/L)
05/21/82	1025	180	<3	<10	7	<0.01	13	12	20	72	<0.10

DATE	TIME	MOLYB-DENUM DISS (UG/L)	NICKEL DISS (UG/L)	PHENOLS (UG/L)	SELE-NIUM DISS (UG/L)	SILVER DISS (UG/L)	STRON-TIUM DISS (UG/L)	VANA-DIUM DISS (UG/L)	ZINC DISS (UG/L)
05/21/82	1025	16	2	7	3	<1	850	7.0	60



1

1/21/76
4/19/76
5/19/76
6/16/76
7/21/76
7/23/76
8/22/76
10/12/76
2/8/77
3/30/77

ALLUVIAL WATER QUALITY
WELL AG-6-1
1976 – 1982

FIGURE 6.4-12

The changes in water quality over the period of record for wells AG-3-1, AG-3-3, and AG-6-1 are probably due to flushing of the alluvial ground water systems by the White River. This flushing action would be most significant during above-normal upper basin snowmelt runoff periods. There may be some additional unknown factors or time lags involved, since the highest observed water levels do not correspond exactly in time with the lowest observed values in specific conductance. It is believed that the water quality at well AG-6-1 was additionally affected in the earlier years of record by aquifer test discharges from wells P-2 Upper and P-2 Lower. This has been discussed in detail in the WRSP Final Environmental Baseline Report (VTN 1977) and the WRSP Progress Report for Environmental Programs in 1977 (WRSP 1978).

Eight wells were drilled in the White River alluvium in April 1982 near the northwestern corner of Tract Ub as exploration/test holes for an alluvial water supply system for the White River Shale Project. Field and laboratory water quality determinations were made during pump testing. While not formally a part of the alluvial ground water monitoring program, a USGS laboratory analysis of ground water from the test well was reviewed and has been included in the Data Management System for the White River Shale Project. Field water quality measurements were taken by WRSOC staff at the time of pump testing. The water quality data for this well are shown in Table 6.4-10.

6.4.4 Precipitation/Evaporation

6.4.4.1 Precipitation The 1982 water year was an unusually wet year. Historic records indicate an annual average precipitation total of approximately 10.0 inches for the tracts. The tract average for 1982 was 14.60 inches, making 1982 the wettest year in the eight-year data collection period. Table 6.4-11 presents the station precipitation totals for water years 1975 through 1982. As can be seen in the table, all stations exceeded their

TABLE 6.4-10
ALLUVIAL WATER SUPPLY TEST WELL
WATER QUALITY DATA
APRIL 14,1982

DATE	TIME	WATER TEMPER-ATURE (DEG C)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	PH FIELD (UNITS)	TOTAL DISS SOLIDS (SUM) (MG/L)	ALKALI-NITY, LAB (MG/L AS CACO3)	HARD-NESS TOTAL (AS CACO3) (MG/L)	CALCIUM DISS (MG/L)	MAGNE-SIUM DISS (MG/L)	SODIUM DISS (MG/L)	PERCENT SODIUM
04/14/82	1100	9.5	940	7.7	555	220	310	83	25	67	32

DATE	TIME	CHLOR-IDE DISS (MG/L)	SUL-FATE DISS (MG/L)	SILICA DISS (MG/L)	FLUOR-IDE DISS (MG/L)	SULFIDE TOTAL (MG/L AS S)	OXYGEN DEMAND, CHEM (HIGH LEVEL) (MG/L)	DIS-SOLVED ORGANIC CARBON (DOC) (MG/L)	AMMONIA DISS (AS N) (MG/L)	NITRITE PLUS NITRATE DISS (AS N) (MG/L)	AMMONIA +ORGAN. NITROGN TOTAL (AS N) (MG/L)
04/14/82	1100	37	190	17	0.30	<0.50	76.0	12	0.430	<0.10	0.80

DATE	TIME	PHOS-PHORUS, ORTHO DISS (AS P) (MG/L)	PHOS-PHORUS, TOTAL (AS P) (MG/L)	ALUM-INUM DISS (UG/L)	ARSENIC DISS (UG/L)	BARIUM DISS (UG/L)	BORON DISS (UG/L)	CADMIUM DISS (UG/L)	CHRO-MIUM DISS (UG/L)	COPPER DISS (UG/L)	IRON DISS (UG/L)
04/14/82	1100	<0.010	0.030	<10	3	94	60	<3	<10	18	18

DATE	TIME	LEAD DISS (UG/L)	LITHIUM DISS (UG/L)	MAN-GANESE DISS (UG/L)	MERCURY DISS (UG/L)	MOLYB-DENUM DISS (UG/L)	PHENOLS (UG/L)	SELE-NIUM DISS (UG/L)	STRON-TIUM DISS (UG/L)	VANA-DIUM DISS (UG/L)	ZINC DISS (UG/L)
04/14/82	1100	2	18	230	<0.10	6	<1	<1	980	<1.0	25

TABLE 6.4-11

ANNUAL PRECIPITATION (IN INCHES)
FOR WATER YEARS 1975-1982

Station	1975	1976	1977	1978	1979	1980	1981	1982
ARA-2		9.60	6.00		9.91	10.52	7.30	15.10
ARA-13		9.20	6.00	6.50	10.33	9.50	7.40	13.80
ARS-9	10.59	10.21			11.29	10.33	8.80	14.00
RA-4					12.89	11.33	9.27	14.10
RB-1							8.92	14.64
RS-10							6.32	14.80
RS-11	8.14				10.57	8.20	7.71	13.92
RS-13	8.57	9.78			9.83	9.69	8.28	15.73
RV-7				8.10	10.30	9.22	8.00	15.41
RV-8	9.09			6.38	11.17	9.08	8.77	14.54

previously recorded maximum. The ten-station network average for 1982 exceeded the long-term average by 146%.

The greatest precipitation for the network was recorded at RS-13, where 15.73 inches were collected. In 1982, RS-13 replaced RA-4 as the station with the highest rainfall total. This is unusual in that RA-4 is approximately 750 feet higher in elevation than RS-13 and RA-4 had been the station with the greatest total precipitation since it was established during the 1979 water year. The lowest network total was measured at ARA-13 (13.80 inches). This is not unusual as ARA-13 consistently records low precipitation totals relative to other stations. At ARA-13, precipitation was recorded on a total of 60 days, with the greatest 24-hour total of 1.1 inches on October 11 and 12, 1981 and July 26 and 27, 1982. The greatest six-hour accumulation was 1.0 inches on July 26 and 27, 1982.

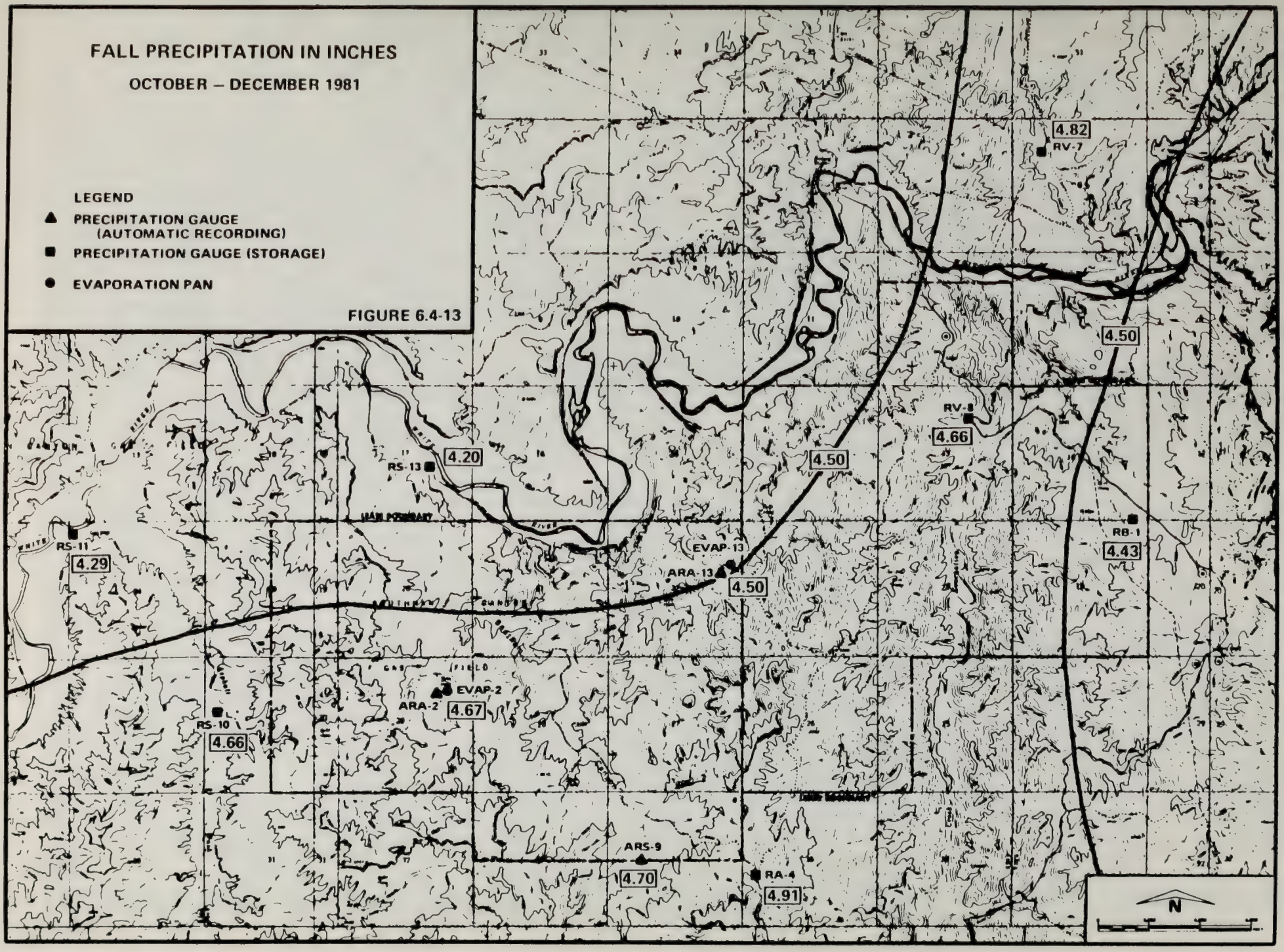
A summary of the 1978 through 1982 seasonal precipitation totals are presented in Table 6.4-12. As seen from the table, summer (July through September 1982) and fall (October through December 1981) precipitation exceeded typical seasonal totals. A check of summer data in Table 6.4-12 points out the variable nature of summer precipitation, which has a range of 6.1 inches over a five-year record. Winter (January through March 1982) and spring (April through June 1982) reported slightly lower than normal seasonal totals.

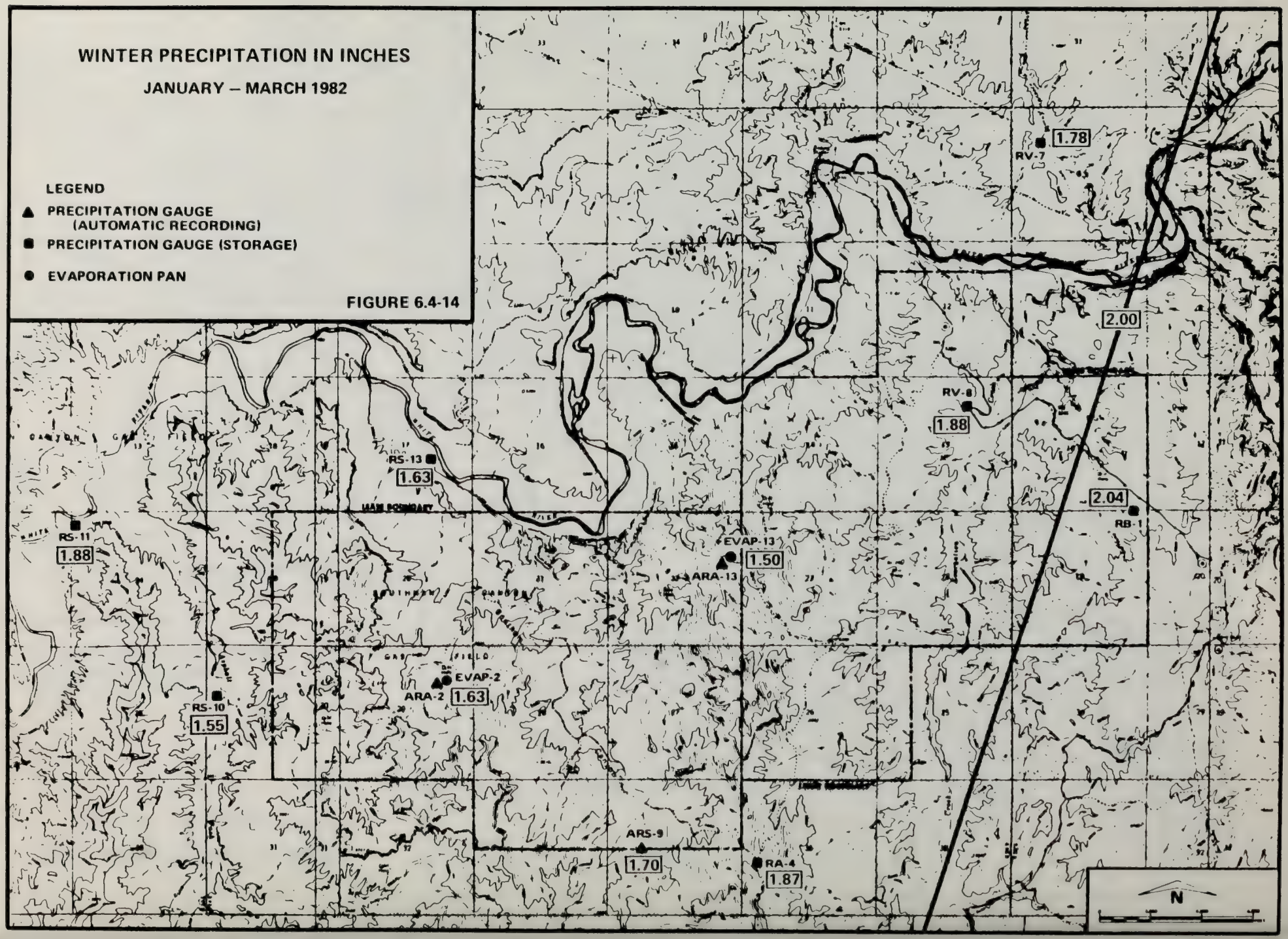
Seasonal isohyetal analyses are presented in Figures 6.4-13 through 6.4-16. Typically, fall and winter precipitation has been the result of synoptic scale storms, while spring and summer events were due to localized thunderstorm cells. Synoptic storms result in a fairly uniform distribution of precipitation across the tracts. Thunderstorms, on the other hand, usually result in highly variable precipitation between gauges. The 1982 water year

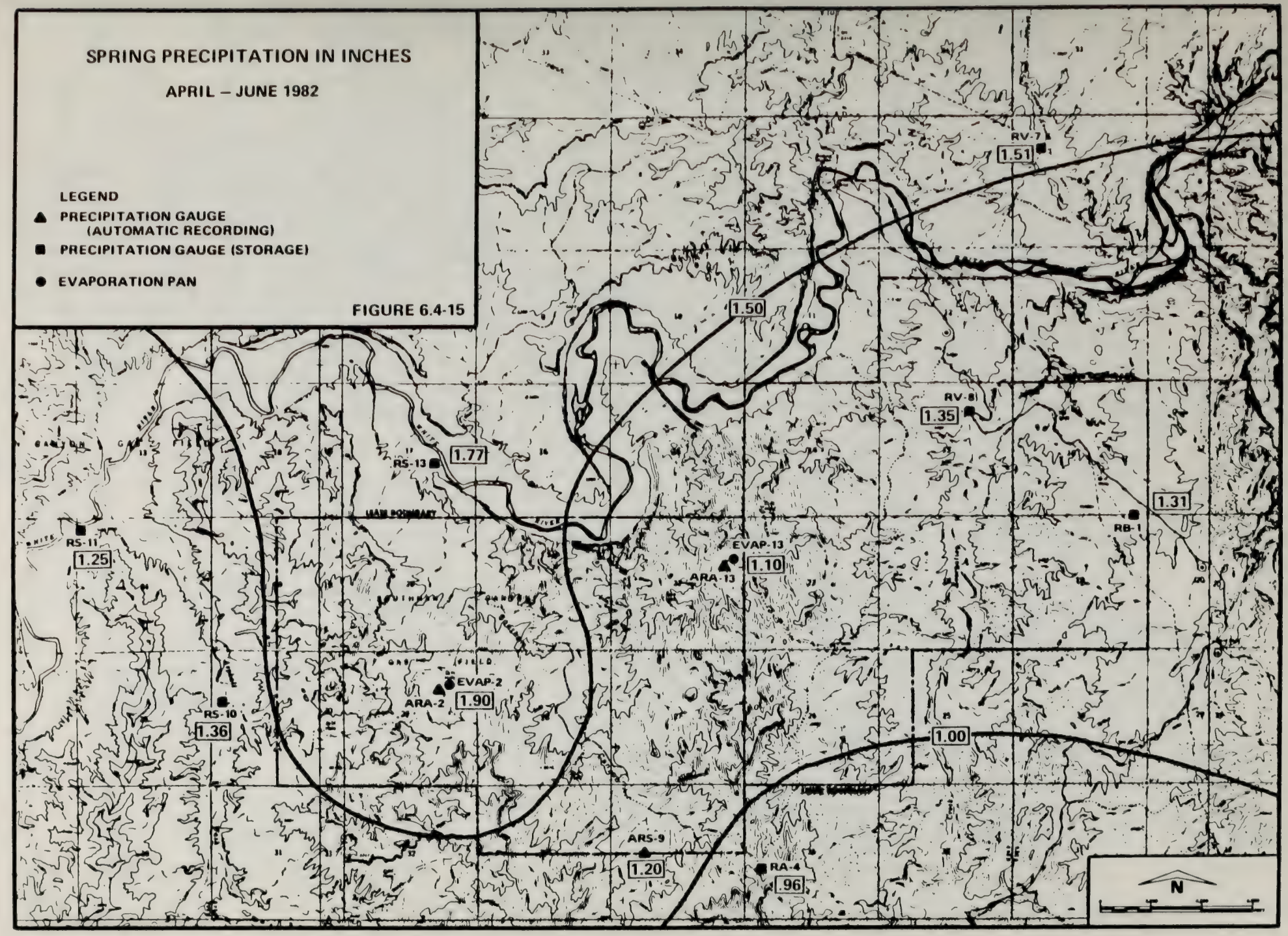
TABLE 6.4-12

SEASONAL PRECIPITATION (IN INCHES)
FOR WATER YEARS 1978-1982

	Fall	Winter	Spring	Summer	Total
1978	2.69	2.28	1.34	0.80	7.11
1979	2.88	3.46	2.19	2.26	10.79
1980	2.39	2.60	1.36	3.41	9.76
1981	1.60	1.37	2.60	2.50	8.07
1982	4.58	1.75	1.37	6.90	14.60
Mean	2.83	2.29	1.77	3.17	10.06


FALL PRECIPITATION IN INCHES
OCTOBER – DECEMBER 1981
LEGEND
PRECIPITATION GAUGE (AUTOMATIC RECORDING)
PRECIPITATION GAUGE (STORAGE)
EVAPORATION PAN
FIGURE 6.4-13
RV-7
4.82
4.50
RV-8
4.66
4.50
RS-13
4.20
RB-1
4.43
RS-11
4.29
EVAP-13
ARA-13
4.50
EVAP-2
ARA-2
4.67
RS-10
4.66
ARS-9
4.70
RA-4
4.91
N


WINTER PRECIPITATION IN INCHES
JANUARY – MARCH 1982
LEGEND
PRECIPITATION GAUGE (AUTOMATIC RECORDING)
PRECIPITATION GAUGE (STORAGE)
EVAPORATION PAN
FIGURE 6.4-14
RV-7
1.78
2.00
RV-8
1.88
2.04
RB-1
RS-13
1.63
RS-11
1.88
EVAP-13
1.50
ARA-13
EVAP-2
ARA-2
1.63
RS-10
1.55
ARS-9
1.70
RA-4
1.87
N


SPRING PRECIPITATION IN INCHES
APRIL – JUNE 1982
LEGEND
PRECIPITATION GAUGE (AUTOMATIC RECORDING)
PRECIPITATION GAUGE (STORAGE)
EVAPORATION PAN
FIGURE 6.4-15
RV-7
1.51
1.50
RV-8
1.35
1.31
RB-1
RS-13
1.77
RS-11
1.25
EVAP-13
1.10
ARA-13
EVAP-2
ARA-2
1.90
RS-10
1.36
1.00
ARS-9
1.20
RA-4
.96
N

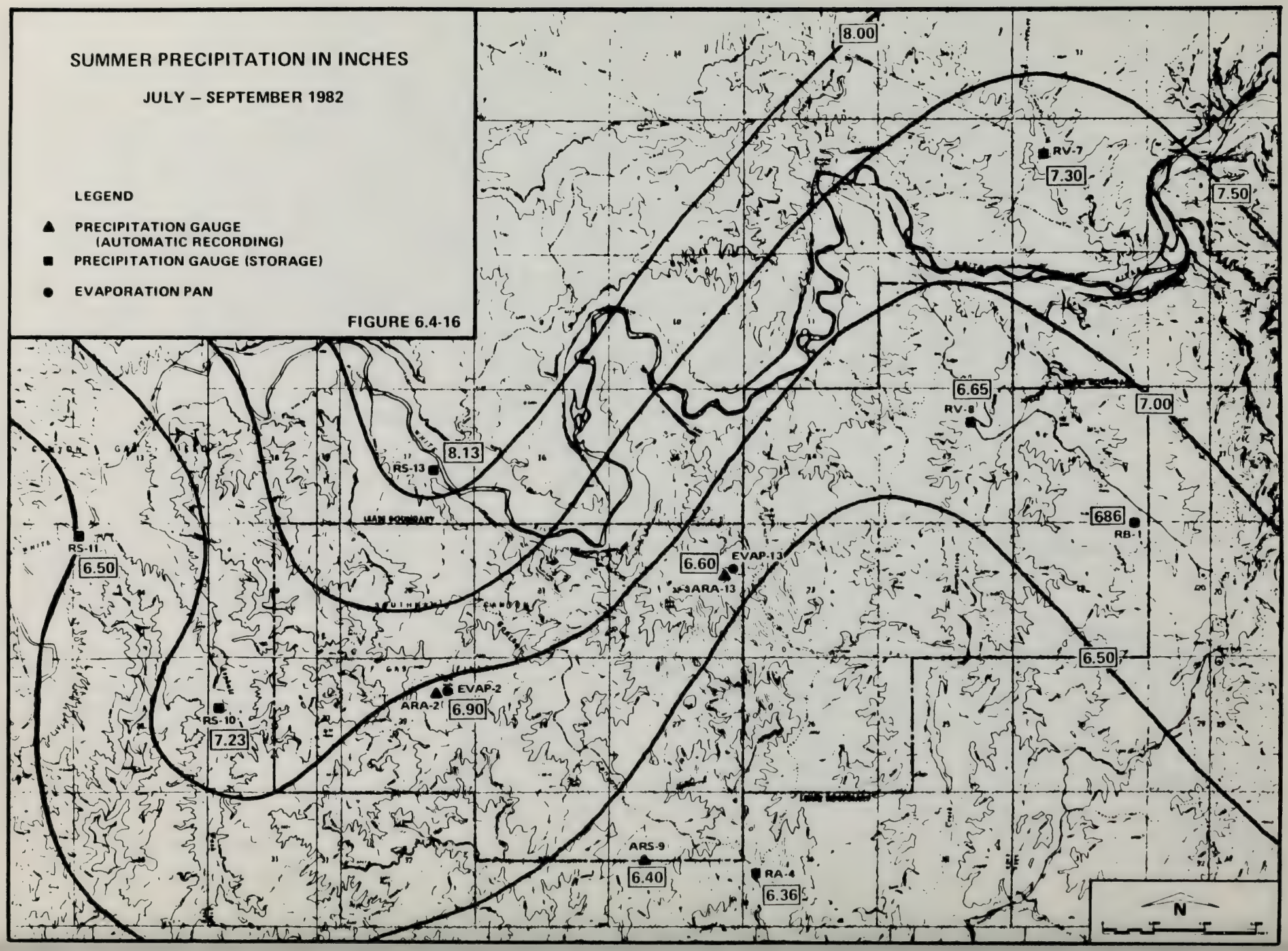

SUMMER PRECIPITATION IN INCHES
JULY – SEPTEMBER 1982
LEGEND
PRECIPITATION GAUGE (AUTOMATIC RECORDING)
PRECIPITATION GAUGE (STORAGE)
EVAPORATION PAN
8.00
RV-7
7.30
7.50
6.65
RV-8
7.00
8.13
RS-13
686
RB-1
RS-11
6.50
6.60
EVAP-13
ARA-13
6.50
EVAP-2
ARA-2
6.90
RS-10
7.23
ARS-9
6.40
RA-4
6.36
N

FIGURE 6.4-16

revealed large deviations from the patterns that have typified the past several years. The greatest inconsistency was found in the summer data.

Relative to total annual precipitation, summer (Figure 6.4-16) was the dominant season of the water year, contributing 47% of the total annual precipitation. Most of the summer precipitation originated from large synoptic storms. Thunderstorms did occur, but precipitation associated with these localized events was secondary to synoptic rainfall. This change resulted in a dramatic shift from previous seasonal patterns. More precipitation fell in the north and northwest portion of the tracts than in the south and southeast. Little correlation was found between altitude and precipitation across the tracts.

The fall (Figure 6.4-13) and winter (Figure 6.4-14) seasonal patterns were consistent with previously reported patterns. Frontal precipitation resulted in fairly uniform precipitation across the tracts. Fall and winter isohyetal analyses show a slight correlation between altitude and precipitation. Fall contributed 31% of the annual precipitation total, while winter contributed 12% of the total.

The 1982 spring precipitation pattern (Figure 6.4-15) resulted from the combined effects of localized thunderstorms and synoptic storms with thunderstorms being dominant. Normally, the highly variable spring precipitation is influential in the annual pattern. However, in 1982, spring was relatively dry compared to fall and summer. Spring contributed only 10% of the annual total and, thus, failed to significantly affect the annual pattern. Annual isohyetal analysis is presented in Figure 6.4-17. Typically, precipitation is lower in the west and northwest portions of the tracts and gradually increases toward the south and southeast. The 1982 pattern is the inverse of the typical pattern with higher precipitation in the west and northwest gradually decreasing toward the south and southeast.

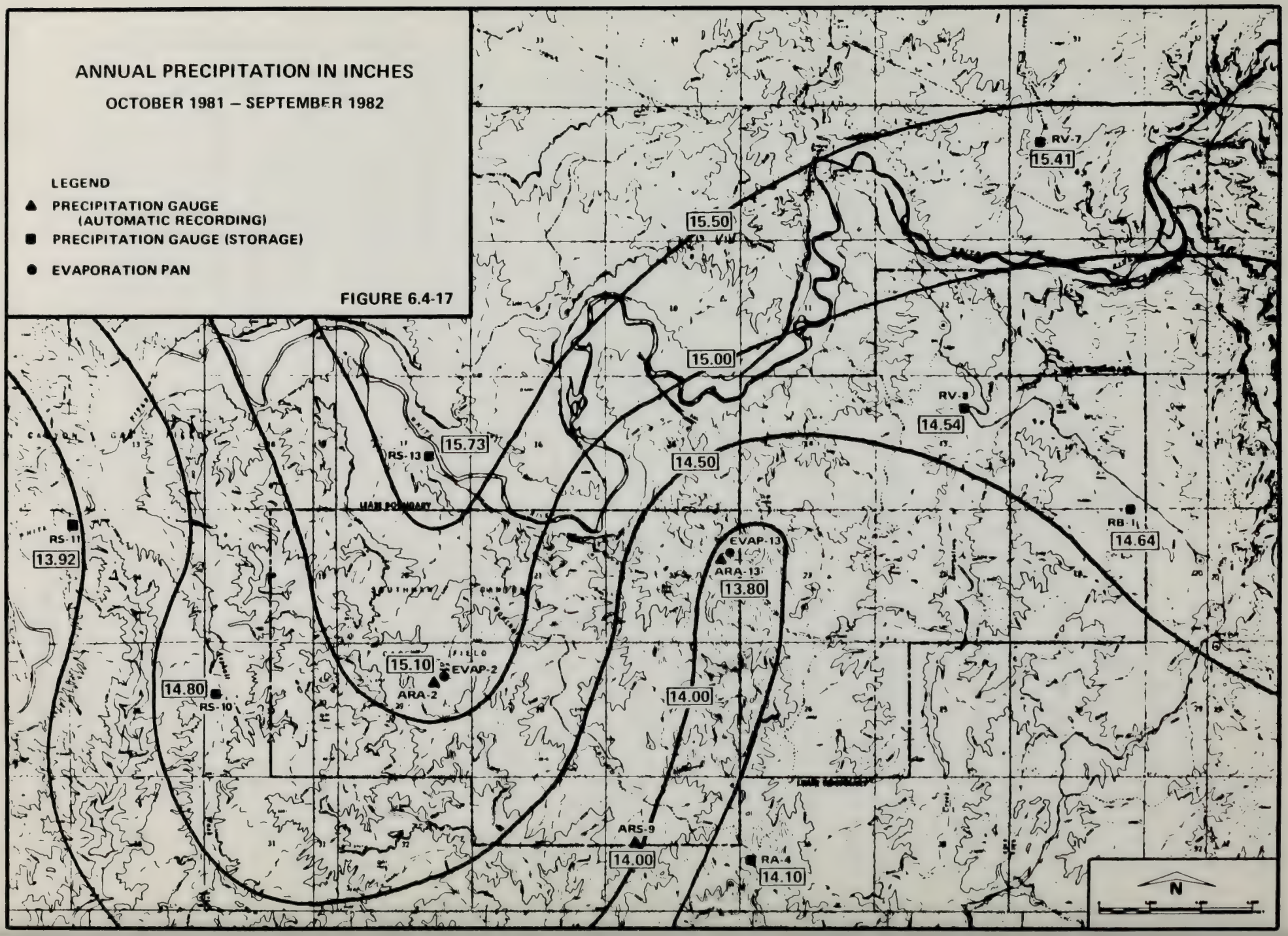

ANNUAL PRECIPITATION IN INCHES
OCTOBER 1981 – SEPTEMBER 1982
LEGEND
PRECIPITATION GAUGE (AUTOMATIC RECORDING)
PRECIPITATION GAUGE (STORAGE)
EVAPORATION PAN
RV-7
15.41
15.50
15.00
RV-8
14.54
15.73
RS-13
14.50
RB-1
14.64
RS-11
13.92
EVAP-13
ARA-13
13.80
15.10
EVAP-2
ARA-2
14.80
RS-10
14.00
ARS-9
14.00
RA-4
14.10
N

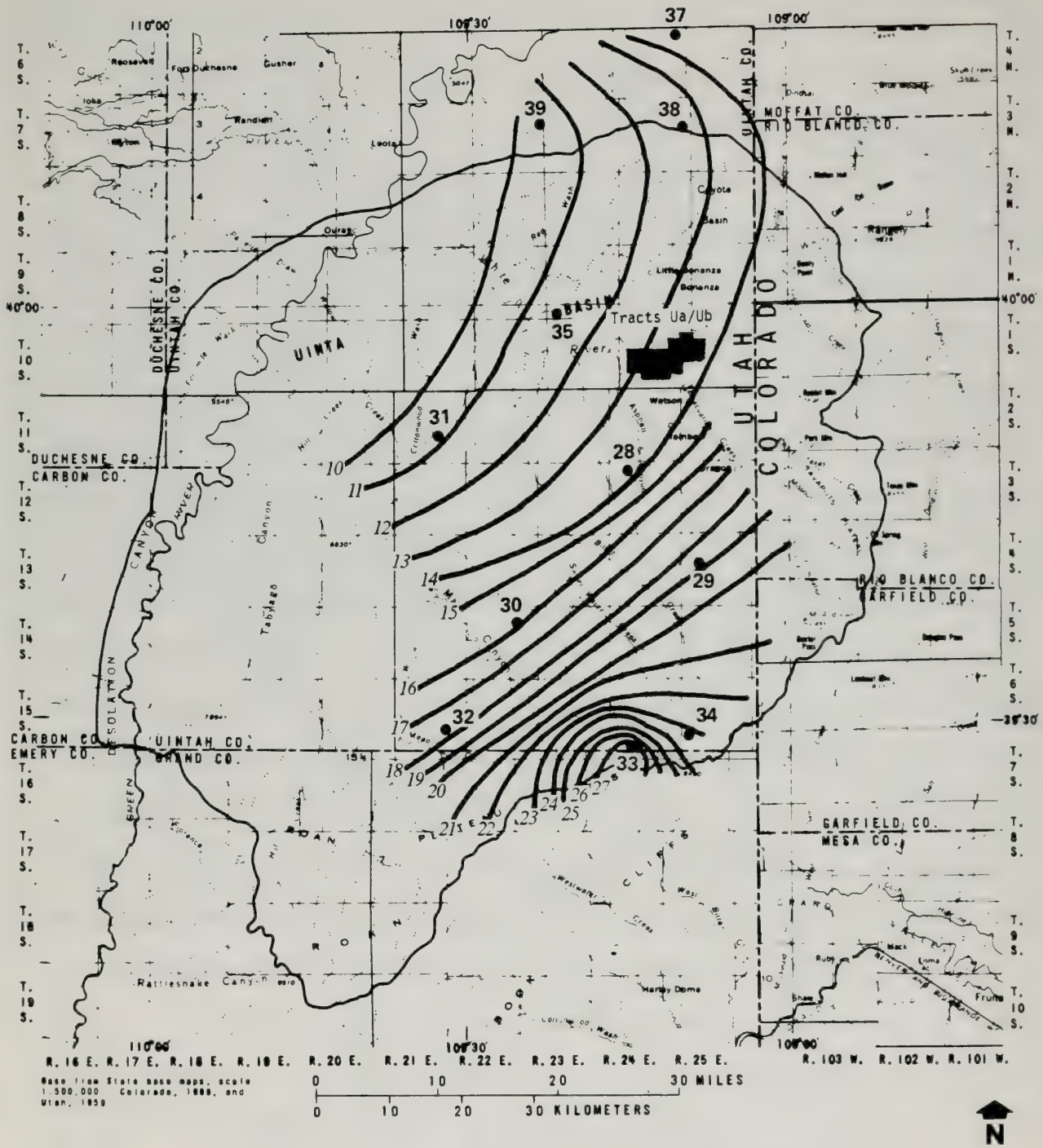
FIGURE 6.4-17

This pattern reversal may be partially attributed to the dominance of synoptic storms which occurred during the fall, winter, and summer. The greater contributions of synoptic storms increased the proportion of relatively uniform precipitation across the tracts. Large-scale slow-moving storms tend to smooth out minor orographic effects across the small scale of the tracts.

The regional precipitation pattern for BLM gauges noted in previous years continued during the 1982 water year. Figure 6.4-18 presents the 1982 annual isohyetal analysis for the BLM precipitation network. The low-lying northwest portions of the Uinta Basin received less precipitation than the higher Roan Plateau in the south. Annual precipitation ranged from a high of 27.3 inches at South Canyon (station 33) to a low of 10.2 inches at Baser Wash (station 39). The BLM network measured a 140% increase in 1982 annual precipitation above the historic average. This percentage increase approximates the 146% increase measured by the WRSOC network. The 13- and 14-inch isohyets bracket the majority of the tract area, providing an estimation of annual tract precipitation. The 13- to 14-inch estimate is within 10% of the average developed from the WRSOC gauge network. While the BLM network may provide reasonable estimates for tract precipitation, it is unable to provide in-depth analysis of annual and seasonal tract pattern shifts. The large difference in scale between the BLM and WRSOC networks prevents such analysis.

Table 6.4-13 presents the monthly data which are used in compiling the annual and seasonal (Table 6.4-14) totals for the 1982 water year.

6.4.4.2 Evaporation The two evaporation pans are located in Southam Canyon (EVP-2) and the plant site (EVP-13). Evaporation data were collected during the freeze-free period of May through September. Table 6.4-15 presents a monthly summary of the data collected from the two sites. Total pan evaporation at EVP-2 and EVP-13 for the freeze-free period were 27.09 inches and



BLM REGIONAL PRECIPITATION NETWORK
ANNUAL PRECIPITATION IN INCHES

OCTOBER 1981 – SEPTEMBER 1982

33 PRECIPITATION NETWORK STATION

10 PRECIPITATION ISOHYETAL

FIGURE 6.4-18

TABLE 6.4-13

MONTHLY PRECIPITATION (IN INCHES)
OCTOBER 1981-SEPTEMBER 1982

Station	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
ARA-2	3.80	0.55(1)	0.32(1)	0.27(1)	0.10(1)	1.26(1)	0.30	1.40	0.20	1.10	2.80	3.00	15.10
ARA-13	3.70	0.50	0.30	0.30	0.10	1.10	0.10	1.10	0.00	1.50	2.00	3.10	13.80
ARS-9	3.70	0.57(2)	0.43(2)	0.29(2)	0.10(2)	1.31(2)	0.10	1.00	0.10	1.10	1.90	3.40	14.00
RA-4	3.70(3)	0.56	0.65	0.31	Trace	1.56	Trace	0.86	0.10	1.23	1.90(3)	3.23	14.10
RB-1	3.35	0.55	0.53	0.43	Trace	1.61	Trace	1.22	0.09	1.76	1.73	3.37	14.64
RS-10	3.65	0.66	0.35	0.27	Trace	1.28	Trace	1.19	0.17	1.45	2.56	3.22	14.80
RS-11	3.40	0.62	0.27	0.43	Trace	1.45	Trace	1.14	0.11	1.23	1.83	3.44	13.92
RS-13	3.39	0.50	0.31	0.24	Trace	1.39	Trace	1.60	0.17	1.68	2.82	3.63	15.73
RV-7	3.80	0.66	0.36	0.42	Trace	1.36	0.10	1.33	0.08	0.97	3.03	3.20	15.41
RV-8	3.80	0.54	0.32	0.43	Trace	1.45	Trace	1.26	0.09	1.45	1.88	3.32	14.54
Mean Monthly Total	3.63	0.57	0.38	0.34	0.03	1.38	0.06	1.21	0.11	1.35	2.25	3.30	14.60

(1) Value estimated based on data from stations RS-10, RS-13 and ARA-13.
(2) Value estimated based on data from stations RA-4, ARA-13 and RS-10.
(3) Value estimated based on data from stations ARS-9, ARA-2, RV-8 and ARA-13.

TABLE 6.4-14

SEASONAL PRECIPITATION (IN INCHES)
OCTOBER 1981-SEPTEMBER 1982

Station	Fall	Winter	Spring	Summer	Annual Total
ARA-2	4.67	1.63	1.90	6.90	15.10
ARA-13	4.50	1.50	1.10	6.60	13.80
ARS-9	4.70	1.70	1.20	6.40	14.00
RA-4	4.91	1.87	0.96	6.36	14.10
RB-1	4.43	2.04	1.31	6.86	14.64
RS-10	4.66	1.55	1.36	7.23	14.80
RS-11	4.29	1.88	1.25	6.50	13.92
RS-13	4.20	1.63	1.77	8.13	15.73
RV-7	4.82	1.78	1.51	7.30	15.41
RV-8	4.66	1.88	1.35	6.65	14.54
Seasonal Arithmetic Mean	4.58	1.75	1.37	6.90	14.60
% of Annual Total	31	12	10	47	100

TABLE 6.4-15

1982 PAN EVAPORATION
AT STATION EVP-2

Period	Net Pan Evaporation (in)	Precip-itation (in)	Pan Coefficient	Total Pan[a] Evaporation (in)
5/3-6/1	4.00	1.20	0.95	4.94
6/2-7/2	6.48	0.20	0.95	6.35
7/3-8/2	6.40	1.10	0.95	7.13
8/3-8/31	3.33	2.80	0.95	5.82
9/1-9/22	1.80	1.20	0.95	2.85
Total for Period	22.01	6.50		27.09

1982 PAN EVAPORATION
AT STATION EVP-13

Period	Net Pan Evaporation (in)	Precip-itation (in)	Pan Coefficient	Total Pan[a] Evaporation (in)
5/4-6/1	3.53	0.50	0.95	3.83
6/2-7/2	6.33	0.00	0.95	6.01
7/3-8/2	6.25	1.40	0.95	7.27
8/3-8/31	3.35	2.00	0.95	5.08
9/1-9/22	1.40	1.30	0.95	2.57
Total for Period	20.86	5.20		24.76

(a) Total evaporation equals (Net Pan Evaporation + Precipitation) x Pan Coefficient.

24.76 inches, respectively. The 1982 results were slightly lower than 1981 total pan evaporation values (EVP-2, 28.06 inches and EVP-13, 25.62 inches).

The relationship between evaporation and wind run, relative humidity and mean air temperature is well understood. Generally, evaporation is directly related to wind run and mean air temperature, while evaporation and relative humidity are inversely related. Figure 6.4-19 presents a plot of the 1982 evaporation, wind run, mean air temperature and relative humidity data for EVP-2. The data presented in this figure follow the expected pattern. Evaporation peaks coincide with increased wind run and air temperature and decreased relative humidity. The major exceptions to this pattern occurred in July when evaporation increased despite a decrease in wind run. In this case, the increased evaporation may be attributed to the high air temperatures (warmest month of the freeze-free period) and low relative humidity (lowest month of the freeze-free period).

STATION EVP-2

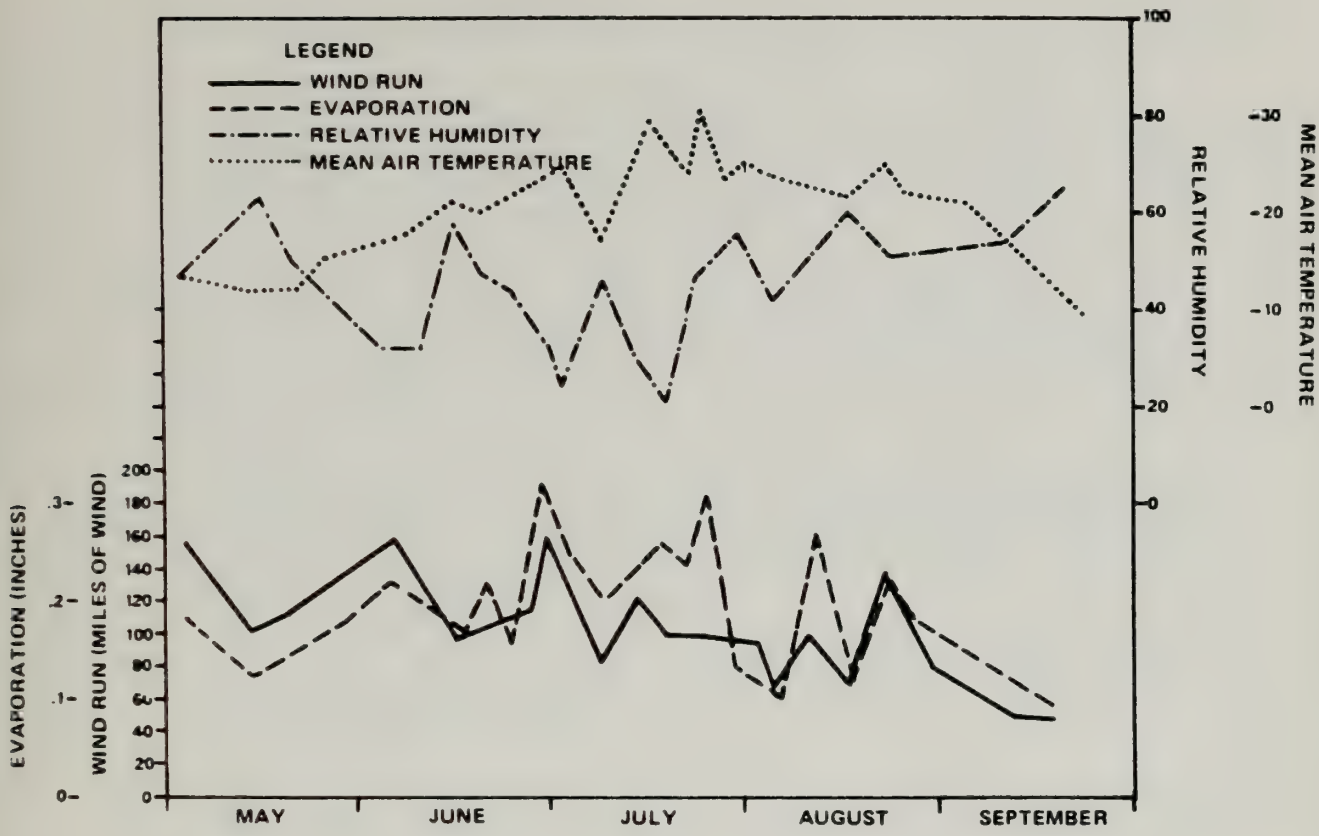


FIGURE 6.4-19

TOTAL PAN EVAPORATION, WIND RUN, MEAN AIR TEMPERATURE AND RELATIVE HUMIDITY

MAY – SEPTEMBER 1982

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SPECIAL STUDIES

7.0 SPECIAL STUDIES

The White River Shale Oil Corporation has identified several areas of study important to our evaluation of the environmental impacts of development on Tracts Ua and Ub. During 1982, the major area of study involved reclamation research. In future years studies will be expanded into other areas as outlined in the "Environmental Monitoring Manual."

7.1 RECLAMATION RESEARCH

7.1.1 INTRODUCTION

Reclamation research during 1982 was a combination of several ongoing studies and studies initiated either in late 1981 or in 1982. Each study is directed to one or several of the "questions to be answered" itemized in the 1982 White River Shale Oil Corporation Environmental Monitoring Manual (EMM Sec. 7.2.3). Recently initiated research includes the establishment of a topsoil storage pile to identify any changes in soil microbiology that may occur with long term storage and to evaluate methods of stabilizing soil storage piles. In the fall of 1981, a study was begun to assess various methods for enhancing wildlife habitat on areas adjacent to the plant site and processed shale disposal areas. Other evaluations conducted during 1982 were ongoing studies. These include the processed shale plant succession study started in 1981; evaluation of root growth in processed shale, an ongoing project since 1979; soil and plant tissue analysis indicating plant tolerance levels and salt buildup now in its fourth year; and plant establishment plots both on disturbed areas and processed shale, also started in 1979. In addition to the field studies, several greenhouse studies were conducted in 1982. They included analyses of the physical and chemical properties of circular grate processed shale and the response of seed germination and growth to those characteristics.

The reclamation research completed to date has provided information pertinent to the revegetation of disturbed areas and of processed shale. Plants species have been identified and methodologies tested that will pro-

vide valuable direction in meeting the criteria for successful revegetation for oil shale tracts Ua & Ub. Reclamation research for the WRSP continues under the direction of Dr. Cyrus M. McKell of Native Plants, Inc.

7.1.2 PROGRAM SUMMARY

7.1.2.1 Annual Plant Succession on Processed Shale. The natural plant succession onto processed shale disposal piles at Anvil Points was again evaluated in 1982. In 1981, three transects were established and photographed. Those same transects were again photographed in 1982. In addition, the average percentage of plant cover and litter cover was estimated in June of 1982. It was found that there was approximately 6% annual plant cover and 8% litter cover. The pH of the soil samples taken from the pile was 7.88 in those areas with plant cover and slightly higher, 8.53, in areas void of vegetation. Electrical conductivity (EC) showed a similar trend, 2.40 mmhos/cm in vegetated areas and 8.60 mmhos/cm in areas of bareground.

7.1.2.2 Root Growth in Shale. Observations on root growth into processed shale made in 1981 were again evident in 1982. Western wheatgrass is spreading from the soil trenches at Anvil Points into adjacent processed shale. This was true for most of the grass species used in the seedling experiment.

7.1.2.3 Plant Establishment Studies.

A. Migration of Salts in Soil Trenches. Analysis of the soil filled trench at Anvil Points followed the format used in 1981. Differences in pH, EC or elemental content between soil or shale levels were negligible in 1982. The only significant difference was with pH. It was higher at the 60 cm shale

level than any other soil samples, but not significantly higher than the surface or 15 cm shale samples. After two years since its establishment, only a few changes in the salt content, pH and EC are evident at the various soil and shale depths. A significant decrease from 1981 to 1982 in the amount of Calcium (Ca) was found at all three shale levels. Also, the amount of Magnesium (Mg) decreased at the 15 cm shale, 15 cm soil and 60 cm shale depths. The only change in pH occurred at the 60 cm shale level, increasing from 8.14 in 1981 to 8.70 in 1982. Other trends from year to year were noticed, but none were found to be significant statistically. Future years data are needed to confirm these trends.

B. Survival and Growth of Plants in Soil Trenches. From October 1981 to October 1982, six plants were lost at the Anvil Points study site. Three *Atriplex* species were lost: 1 cuneate saltbush from the south soil trench and two fourwing saltbushes, one from the north trench and one from the microenvironment study area. The other three losses included one greasewood and one prostrate kochia from the north soil trench, and a seepweed from the basin plantings. Percentage survival of the species used in the trench plantings, basin plantings and flats plantings as of October 1982 are as follows: fourwing saltbush 95%; shadscale 63%; cuneate saltbush 83%; western wheatgrass 95%; greasewood 95%; prostrate kochia 44%; and seepweed from trench plantings only 40%. Both plant heights and cover values were higher in 1982 indicating that growth continues in the fourth year of the experiment.

7.1.2.4 Topsoil Microbiology

A. Microbiology of Stockpiled Topsoil. The topsoil storage pile

adjacent to the Section 6 study area was sampled for total organic carbon, total bacteria, total fungal hyphae length, respiratory activity, dehydrogenase activity, pH, EC and percent moisture. Populations of vesicular arbuscular mycorrhizal (VAM) fungi were also determined.

Results of the first year's research indicate that microbial activity on the topsoil pile was influenced most strongly by the availability of water. No other overriding chemical, physical or biological influence on microbial activity was detected. After one year of storage, microbial populations and activity were generally comparable to those undisturbed soils in the area.

B. Seeding Trials. The topsoil stockpile established and seeded in the fall of 1981 with a grass and shrub mixture was evaluated for seeding success in October of 1982. Two seeding treatments were applied to the stockpile, one in which the seed was braodcast only and one where the seed was broadcast and raked in. Ten seedlings of big sagebrush and two of greasewood were found on the raked area. Only one sagebrush species was found on the unraked area and no seedlings were encountered on the control area. Approximately 30% of the storage pile was covered with annual species.

7.1.2.5 Interseedings and Interplanting for Wildlife Habitat Enhancement. Two areas, one with substantial annual plant cover and one with less than 5% annual plant cover, were seeded with a standard shrub/grass mix in October of 1981. Seed application was drill and broadcast. A few seedlings were observed in the drill seeded area in June 1982, but by fall none were observed in the entire seeded area.

Transplants of big sagebrush, fourwing saltbush, gardner's saltbush and

rubber rabbitbrush were planted in areas of high annual plant cover and bare-ground. In June of 1982 plants of all four species were found although survival percentages varied; sagebrush 85%; fourwing saltbush 92%; gardner's saltbush 23%; and rubber rabbitbrush 46%. Only sagebrush and fourwing saltbush survived until October of 1982. Sagebrush and fourwing saltbush were found in the area with heavier annual plant cover in June. By fall, only sagebrush survived. The greatest cause of mortality during the period from June to October was probably rodents and rabbits. The results of heavy grazing was seen on the majority of the nonliving species as well as those still showing signs of growth.

7.1.2.6 Greenhouse Studies.

A. Freeze/Thaw Effect on Physical Properties of Circular Grate Processed Shale. The effect of freeze/thaw cycles on the physical properties of circular grate processed shale was evaluated in the laboratories of Native Plants, Inc. After 31 freeze/thaw cycles, the particle size of 84% of the shale sampled decreased from the original particle size of 6.35 mm or larger. EC and pH also decreased.

B. Leaching Experiment. An experiment to evaluate the effects of leaching on the chemical properties of circular grate processed shale was conducted in the fall of 1982. One pore volume of material has been leached, to date. Subsequent pore volume experiments will continue in 1983. The leachate of the first pore volume contained 90% of the available calcium, 15% magnesium, 18% of the sodium and 89% of the available potassium contained in the unleached shale. With the increase in the amount of salts came an increase in

pH and EC of the leachate as well as the sodium absorption ratio (SAR).

C. Seedling Survival and Growth on Circular Grate Processed Shale. Seedlings of twelve species of grasses, forbs and shrubs were germinated and grown for a short period in a standard soil mix. They were then transplanted to flats of circular grate processed shale.

D. Seed Germination in Union B Processed Oil Shale. An experiment was designed and conducted to provide data on the germination of the seeds of various range plants in processed oil shale. Of the 15 species tested, seeds of 11 of the species germinated in processed shale plots established at the corporate headquarters of NPI. Russian wildrye, northern sweetvetch and needle and thread grass, and to some extent, fourwing saltbush showed the greatest germination success. Only the plots receiving 13 mm water per day showed seedling emergence.

7.1.3 PROGRAM DESCRIPTION

7.1.3.1 Objectives The objective of the reclamation research conducted by Native Plants, Inc. is for the ultimate development of a successful revegetation plant for the oil shale tracts Ua & Ub. Several secondary objectives have directed the efforts in reclamation research. These include the:

- characterization of processed shale relative to its reclamation potential,
- determination of the tolerance and response of various plant species to disturbed areas and processed shale for reclamation and enhancement of wildlife habitat,
- development of plant establishment methods for processed shale

disposal areas and disturbed sites, and

- measurement of the response of microbial activity in topsoil storage piles to long term storage.

7.1.3.2 Study Site Locations. Reclamation research has been conducted at several sites on or adjacent to oil shale tracts Ua & Ub since the acquisition of baseline data in 1975. Since that time, two areas have been designated for ongoing research studies. One is at Anvil Points, Colorado, and the other at Section 6 near Bonanza, Utah. The layout of both study sites has been presented in previous reports (see the 1980 final report for the field plot designed and layout at Anvil Points and the 1982 report for studies at Section 6).

7.1.3.3 Quality Assurance/Quality Control. Precautions were taken to assure that the quality of the research conducted would meet those guidelines outlined in the EMM (Section 3.3.1 and 3.3.2). In some cases, the scope of the project was simplified to allow adequate sampling and greater confidence of the results. All reclamation research studies were set up and conducted to test one of several hypotheses detailed in the EMM (Section 7.2.3).

7.1.4 PROGRAM RESULTS AND ANALYSIS

7.1.4.1 Annual Plant Invasion of Shale Disposal Piles. Weedy annuals (*Salsola kali*, *Halogeton glomeratus*, *Kochia scoparia*, *Mentzelia albicaulis*) were noted growing in the processed shale pile, as early as 1977. These species growing in the shale pile have invaded the site from external natural seed sources. Photographs were taken along the three transects (Figure 7.1-1, 7.1-2, 7.1-3) marked in 1981. A .25 m^2 quadrat subdivided into 100 equal

areas was placed along each transect. Total cover was estimated and the number of seedlings counted in ¼ of the quadrat (lower right quadrat). A summary of density, percent live cover, and percent litter cover of the above species are given in Table 7.1-1. There was an average of almost 6% total living cover and an additional 8% litter cover. The plants were in the seedling stage which may explain the lower percentage cover with respect to the 1981 estimate. Although several annual species were present, only annual kochia was encountered along the transects.

Figure 7.1-1. West transect on shale disposal pile at Anvil Point, Colorado.

Table 7.1-2 contains pH, EC and elemental analysis values for shale samples collected from the surface of the shale disposal pile. Samples of

Table 7.1-1. Density and percentage cover of annual plant species and percentage litter cover on shale disposal piles at Anvil Points, Colorado, June, 1982.

		Annual Plant Density					
WEST TRANSECT	Replication	HAGL[1]	KOSC	MEAL[1]	SAKA[1]	% Live Cover	% Litter Cover
	1		139			9	15
	2		148			4	25
	3		61			8	10
	4		18			2	1
	5		75			7	2
Transect Avg.		0	88.2	0	0	6.0	10.6
CENTER TRANSECT							
	1		256			18	15
	2		148			4	.5
	3		29			1	10
	4		0			.1	1
	5		5			.2	3
Transect Avg.		0	87.6	0	0	4.7	5.9
EAST TRANSECT							
	1		0			0	5
	2		5			2	7
	3		161			21	8
	4		78			5	15
	5		6			.8	8
Transect Avg.		0	50.0	0	0	5.8	8.6
Area Avg.		0	75.3	0	0	5.5	8.4
Standard Deviation			21.9			0.7	2.3

[1]Present on shale disposal pile but not encountered along transects.

Table 7.1-2. pH, EC elemental content and saturation percentage of processed shale material (surface 1-2cm) on the annual plant succession study area at Anvil Points, Colorado, June, 1982.

Location	pH	EC	Elemental Content (ppm)								SO_4 meq/l	% Saturation
			As	Cd	Se	Mo	B	Ca	Mg	Na		
WITH LIVING COVER												
Adjacent W. Transect	7.83	2.20	51	0.5	0.9	18	50	1270	915	165	65	4.31
Adjacent Cntr. Transect	7.79	1.60	---	---	---	23	55	1285	905	110	70	4.36
Adjacent E. Transect	8.01	3.40	46	0.7	0.8	20	35	1205	1070	440	50	6.56
Average	7.88	2.40	48.5	0.6	0.85	20	47	1253	963	238	62	5.08
Standard Deviation	0.12	0.92	3.5	0.2	0.07	2.5	10	43	93	177	10	1.28
VOID OF LIVING COVER												
Adjacent W. Transect	8.64	12.20	52	0.6	2.9	39	45	1075	2280	1415	25	2.82
Adjacent Cntr. Transect	8.60	6.92	52	0.7	1.8	33	20	970	1800	370	35	3.17
Adjacent E. Transect	8.36	6.68	44	1.3	0.9	20	45	1155	1320	470	75	2.76
Average	8.53	8.60	49	0.9	1.9	31	37	1067	1820	752	45	2.92
Standard Deviation	0.15	3.12	5	0.4	1.0	10	14	93	480	577	26	0.22
t value	-33.08**	-4.90**	-.98^{ns}	-11.19**	-5.37**	-2.30^{ns}	.68^{ns}	3.12*	-2.98*	-1.48^{ns}	0.83^{ns}	-1.12^{ns}
df	4	4.	3	3	3	4	4	4	4	4	4	4

--- insufficient sample material

**difference significant at .01 level
* difference significant at .05 level

shale were collected from areas with live cover and areas void of cover. The pH of the shale sample with living cover was slightly lower than the corresponding bareground sample. A similar observation was made with respect to EC. The EC values of bareground were almost triple the EC of shale samples with living cover.

Of the nine elements analyzed, only four were found to be significantly different between the two shale samples. The cadmium, selenium and magnesium content of the shale areas supporting growth was higher than the areas void of living cover. The amount of calcium was the only element found in significantly higher amounts in the areas with living cover.

Figure 7.1-2. Center transect on shale disposal pile at Anvil Points, Colorado.

Figure 7.1-3. East transect on shale disposal pile at Anvil Points, Colorado.

7.1.4.2 Root Growth in Processed Shale. During excavations for soil analysis in processed shale, rhizomes and smaller roots of *Agropyron smithii* were noted growing in shale material adjacent to the soil filled trench. Also, shrub roots were observed growing throughout the soil trench profile and in the underlying processed shale material. No gross morphological differences were observed between roots growing in soil trench topsoil and the underlying shale material. Photographs of the rhizome, small roots and shrub roots are shown in Figures 7.1-4 and 7.1-5.

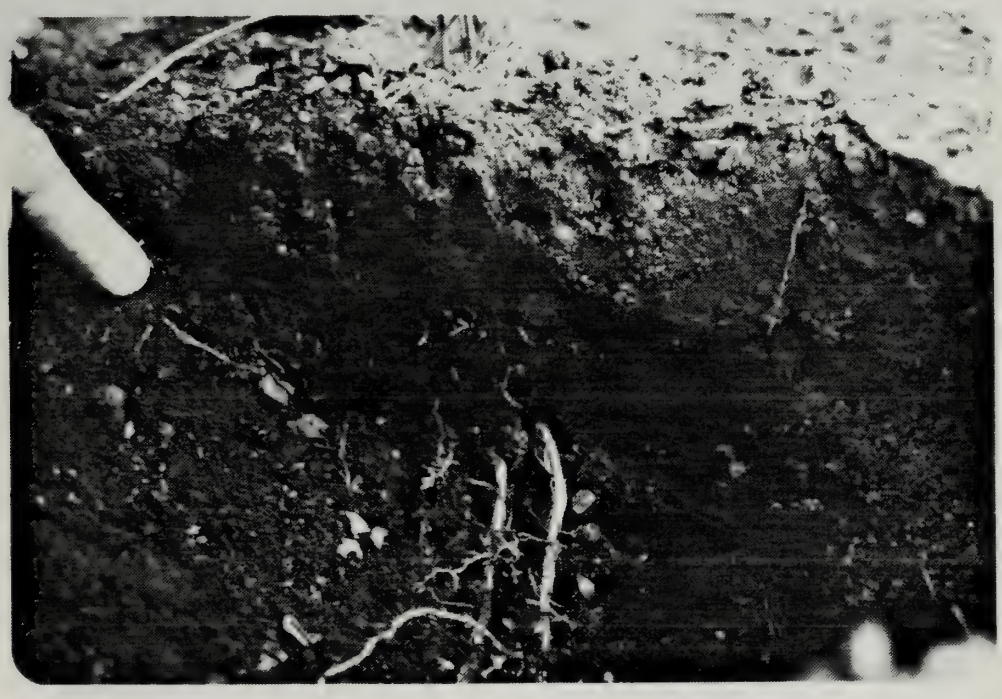


Figure 7.1-4. Roots of Western wheatgrass growing in processed oil shale at Anvil Points, Colorado.

Figure 7.1-5. Western wheatgrass spreading from soil filled trench into processed shale at Anvil Points, Colorado.

7.1.4.3 Migration of Salts. Studies initiated in 1979 at Anvil Points included a topsoil filled trench in a shale disposal pile. The survival of transplants in the soil trenches has been monitored since 1979. Beginning in 1981, soil samples were collected from various depths in the soil trench and adjacent shale and analyzed. The 1981 analyses were repeated in 1982. The results are reported in Table 7.1-3. Some overall trends observed in 1981 were again evident in 1982. The pH, EC, amount of sodium (Na) and arsenic (As) were found to be higher in the shale samples. The amount of Ca

Table 7.1-3. Summary of pH, EC, elemental analyses and saturation percentage of the soil samples taken from the south soil trench at Anvil Points, Colorado, June 1982. Averages followed by a similar letter are not significantly different at the α=.05 level as determined by ANOVA and the Student Newman Kuel (SNK) mean separation test.

Sample/ Location	Substrate	pH	EC (mmhos/cm^3)	AS (ppm)	Cd (ppm)	Se (ppm)	Mo (ppm)	B (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	SO_4 (meq/l)	% Saturation
East/0.2 cm	Shale	7.74	2.14	57	0.7	5.0	22	55	845	545	255	30	0.61
Center/0.2 cm	Shale	9.30	40.60	59	0.6	4.9	39	50	1170	3170	5925	110	19.99
West/0.2 cm	Shale	8.61	11.05	54	0.8	1.7	44	60	1275	2540	1295	50	2.28
Average		8.55[ab]	17.93[a]	58	0.6	3.9	35	55	1097[c]	2085[a]	2492[a]	63	7.63
Standard Deviation		0.78	20.13	1	0.1	1.9	12	5	224	1370	3018	42	10.74
East/15 cm	Shale	8.03	7.97	62	0.9	5.0	34	55	1195	580	1495	40	1.53
Center/15 cm	Shale	8.93	12.30	62	0.9	5.3	24	50	1290	1330	3905	40	21.56
West/15 cm	Shale	8.55	6.26	52	0.9	1.9	21	65	1220	1460	820	55	14.43
Average		8.50[ab]	8.84[a]	59	0.9	4.1	26	57	1235[c]	1123[a]	2073[a]	45	12.51
Standard Deviation		0.45	3.11	6	0	1.9	7	8	49	475	1622	9	10.15
East/0.2 cm	Soil	7.92	0.90	12	0.4	1.0	6	60	1830	975	135	25	2.69
Center/0.2 cm	Soil	7.90	2.98	7	0.4	0.2	3	55	2010	880	840	35	2.82
West/0.2 cm	Soil	8.42	1.75	45	0.8	2.9	31	65	1225	1230	165	45	2.11
Average		8.08[ab]	1.88[a]	21	0.5	1.4	13	60	1688[b]	1028[a]	380[a]	35	2.54
Standard Deviation		0.29	1.05	21	0.2	1.4	15	5	411	181	399	10	0.38

Table 7.1-3. (cont.)

Sample/ Location	Substrate	pH	EC (mmhos/cm^3)	AS (ppm)	Cd (ppm)	Se (ppm)	Mo (ppm)	B (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	SO_4 (meq/l)	% Saturation
East/15 cm	Soil	7.98	1.00	6	0.5	0.1	1	55	2370	715	425	35	11.80
Center/15 cm	Soil	7.69	3.80	6	0.5	0.1	1	50	2180	750	980	75	9.17
West/15 cm	Soil	7.68	5.39	8	0.5	0.1	2	30	2365	740	330	35	8.60
Average		7.78[a]	3.40[a]	7	0.5	0.1	1	45	2305[a]	735[a]	578[a]	48	9.85
Standard Deviation		0.17	2.22	1	0.1	0	1	13	108	18	351	23	1.71
East/30 cm	Soil	7.98	1.20	4	0.7	0.1	1	50	2135	750	545	45	11.24
Center/30 cm	Soil	7.53	5.52	5	1.2	0.1	2	25	2605	685	1190	75	10.15
West/30 cm	Soil	7.79	7.62	11	0.4	0.1	2	45	2210	770	2200	45	16.31
Average		7.77[a]	4.78[a]	7	0.8	0.1	2	40	2317[a]	735[a]	1312[a]	55	12.57
Standard Deviation		0.23	3.27	4	0.4	0	1	13	253	44	834	17	3.29
East/45 cm	Soil	7.94	2.70	4	0.3	0.1	1	85	2015	740	680	55	10.83
Center/45 cm	Soil	7.83	7.54	4	0.4	0.2	2	40	2010	980	1790	75	15.92
Average		7.89[a]	5.12[a]	4	0.4	0.2	2	63	2013[ab]	860[a]	1235[a]	65	13.38
Standard Deviation		0.08	3.42	0	0.1	0.1	1	32	4	170	785	14	3.60
East/60 cm	Shale	8.31	2.55	57	0.7	4.3	25	60	1360	910	740	70	16.61
Center/60 cm	Shale	8.92	10.42	45	0.5	0.8	26	55	1020	1320	3580	105	23.37
West/60 cm	Shale	8.87	8.72	55	0.5	2.9	26	25	970	1155	2415	75	24.53
Average		8.70[b]	7.23[a]	52	0.6	2.7	26	47	1117[c]	1228[a]	2245[a]	83	21.50
Standard Deviation		0.34	4.14	6	0.1	1.8	1	19	212	284	1428	19	4.28

in the shale samples was lower than the soil samples in 1982, a relationship that was just the reverse in 1981. Sulfate which was first sampled in 1982 was found to be higher at the shale surface than at the 60 cm depth.

Table 7.1-4 compares the soil/shale analyses of 1981 and 1982. The pH of the shale surface decreased from 1981 to 1982, although not significantly. However, there was a slight increase at all other levels. The only significant increase was in the shale at 60 cm. A similar trend was found for EC.

There was a slight increase of Na content at the shale surface and at the 15 cm, 30 cm, 45 cm and 60 cm depths. Only at the soil surface was Na found in lower amounts than in 1981, which may be attributable, in part, to a decrease in evaporation due to vegetation cover. None of the differences were significant at the α=0.05 level.

Calcium, on the other hand, decreased at all levels, however, only significantly in the three shale samples (surface, 15 cm and 60 cm). Magnesium decreased from 1981 to 1982 at the 15 cm shale depth, at the 15 cm soil depth, and in the shale below the topsoil trench (60 cm).

Of the other elements analyzed, only As was found to have changed from 1981. No statistical tests were run because of the detection levels for As set in the 1981 soil analyses. Lower concentrations were found at the shale surface and higher ones at the 60 cm shale depth. Year to year comparisons for other elements was also hindered by detection levels used in 1981.

Although the data are still inadequate to statistically validate any

Table 7.1-4. Summary of pH, EC and elemental analysis of south soil trench at Anvil Points, Colorado, 1981 and 1982. Yearly average values followed by different letters are significantly different at the α=.05 level as determined by ANOVA and SNK mean separation test.

	Na (ppm)		Ca (ppm)		Mg (ppm)		Mo (ppm)		Cd (ppm)		As (ppm)		B (ppm)		Hg (ppm)		SO_4(meq/l)	
	81	82	81	82	81	82	81	82	81	82	81	82	81	82	81	82	81	82
0-2 cm Shale	1725	2492	8108[a]	1097[b]	2768	2085	<25	35	<2.5	.6	32	58	<50	55	157			63
15 cm Shale	2127	2073	10657[a]	1235[b]	3800[a]	1123[b]	<25	26	<2.5	.9	43	59	<50	57	293			45
0-2 cm Soil	491	380	5053	1588	1098	1028	<25	13	<2.9	.5	25	21	<50	60	43			35
15 cm Soil	350	578	3415	2305	950[a]	735[b]	<25	1	<2.7	.5	25	7	<50	45	23			48
30 cm Soil	379	1312	3070	2317	880	735	<25	2	<2.7	.8	25	7	<50	40	18			55
45 cm Soil	522	1235	4740	2013	873	860	<25	2	<2.9	.4	25	4	<50	63	15			65
60 cm Shale	1385	2245	7098[a]	1117[b]	1824[a]	1228[b]	<25	26	<2.5	.6	29	52	<50	47	143			83

	Sat.%		pH			EC(mmhos/cm^3)			Se(ppm)	
	81	82	81		82	81		82	81	82
			June	Oct.	June	June	Oct.	June		
0-2 cm Shale		7.6	8.72	8.70	8.55	7.5	14.6	17.9		3.9
15 cm Shale		12.5	7.94	8.51	8.50	4.3	12.7	8.8		4.1
0-2 cm Soil		2.5	7.90	7.84	8.08	4.4	3.1	1.9		1.4
15 cm Soil		9.9	7.41	7.69	7.78	2.0	2.9	3.4		0.1
30 cm Soil		12.6	7.52	7.63	7.77	3.0	4.4	4.8		0.1
45 cm Soil		13.4	7.64	7.89	7.89	4.7	7.5	5.1		0.2
60 cm Shale		21.5	8.14[a]	8.51[ab]	8.70[b]	6.2	12.5	7.2		2.7

Blank - no data taken

trend, a few observations of the data can be made. It can be seen that salts primarily Na, are accumulating in the soil filled trench (Table 7.1-4). The pH of the topsoil has increased, but only slightly since 1981. The EC values reported for 1982 also show an increase, but again, the trend is only slightly distinguishable. To date, the pH and EC levels have not reached or exceeded deleterious levels that have been previously observed for the halophytic plants used in this study.

7.1.4.4 Plant Establishment Studies. Studies have been conducted since early 1976 to evaluate various techniques that can be used to establish plants in oil shale disposal areas. The information collected in 1982 from each study area includes height, cover, and survival of each planting and the elemental analysis of selected plant tissue samples.

A. Evaluation of Plantings at Anvil Points, Colorado. The six different plantings on the shale disposal pile at Anvil Points were evaluated in June and October of 1982. The height and cover of each living plant was recorded (Tables 7.1-5 to 7.1-8). Mortality in addition to previous observations was also noted. Two fourwing saltbush plants were lost during the 1981 growing season. One was lost in the basin planting and one in the soil/shale microenvironment study. Three other species suffered a single loss, cuneate saltbush in the south trench, seepweed in the north trench, and greasewood in the basin plantings. The average height, cover and percent survival of the plantings at each study site is given in Table 7.1-9. In the soil trench plantings, fourwing saltbush, western wheatgrass and greasewood show 100% survival. Shadscale and cuneate saltbush had a single

Table 7.1-5. Plant height measurements for the south soil trench plantings, basin plantings, north soil trench plantings and flat plantings - Anvil Points, Colorado. June 1982 & October 1982.

SOUTH SOIL TRENCH
HEIGHT (cm)

Replication	Fourwing Saltbush		Shadscale		Cuneate Saltbush		Western Wheatgrass		Greasewood		Prostrate Kochia		Seepweed	
	June	October	June	October	June	October	June	October	June	October	June	October	June	October
I	76	70	M	M	33	32	31	30	91	75	M	M		
II	81	85	16	17	M	M	36	28	102	115			M	M
III	85	85	13	8	27	30	33	30	44	48	49	68		
IV	66	75	21	20	37	35	28	25	76	100			26	28
V	82	85	18	20	24	35	35	25	101	100	M	M		
VI	22	36	12	10	25	28	18	10	48	70			34	32
VII	53	65	10	10	26	28	25	26	37	40	23	50		
VIII	86	85	8	10	M	M	25	20	89	85			31	15
IX	54	45	M	M	7	28	34	38	72	78	36	48		
X	61	60	11	8	31	28	25	22	79	72	26	57	M	M
XI									42	58				
Average	66.6	69.1	13.6	12.9	27.5	30.5	29.0	25.4	71.0	76.5	33.5	54.3	30.3	25.0
Standard Deviation	20.0	17.7	4.4	5.2	9.3	3.1	5.8	7.4	24.4	22.8	11.7	9.3	4.0	8.9
					BASIN PLANTING									
I	54	55	M	M	24	25	63	42	72	70			M	M
II	78	65	M	M	M	10	47	40	58	59			M	M
III	67	62	M	M	M	M	29	42	66	75			41	M
IV	82	95	M	M	M	15	44	40	64	62			M	M
V	44	M	M	M	M	M	M	M	21	M			M	M
Average	65.0	69.3	M	M	24.0	16.7	50.8	41.0	56.2	66.3			41.0	M
Standard Deviation	16.0	17.7	--	--	--	7.6	8.4	1.2	20.3	7.7			--	--

Table 7.1-5. (Cont.)

NORTH SOIL TRENCH

Replication	Fourwing Saltbush June	Fourwing Saltbush October	Shadscale June	Shadscale October	Cuneate Saltbush June	Cuneate Saltbush October	Western Wheatgrass June	Western Wheatgrass October	Greasewood June	Greasewood October	Prostrate Kochia June	Prostrate Kochia October	Seepweed June	Seepweed October
I	58	58	29	26	14	17	35	32	75	72	M	M		
II	92	95	20	20	19	30	32	28	99	110			M	M
III	39	58	19	15	23	28	35	32	87	90	M	M		
IV	56	65	M	M	M	M	28	35	84	90			M	M
V	49	50	11	12	18	25	31	30	52	50	31	35		
VI	79	75	12	10	14	20	38	35	56	55			24	M
VII	36	46	11	10	18	28	33	30	71	65	49	55		
VIII	79	75	12	10	20	18	35	32	102	95			36	48
IX	73	70	14	15	19	25	33	23	56	55	M	M		
X	47	60	13	12	21	22	30	44	56	60	34	35	M	M
XI									96	95				
Average	60.8	65.2	15.7	14.4	18.4	23.7	32.0	32.1	75.8	76.1	38.0	41.7	40.0	48.0
Standard Deviation	19.0	14.3	6.0	5.4	3.0	4.7	3.7	5.4	19.0	20.5	9.6	11.5	8.5	--
					FLAT PLANTING									
I	51	48	10	8	19	18	23	5	26	28			30	38
II	101	105	8	8	30	38	38	20	39	40			50	40
III	59	62	25	20	35	30	38	30	62	64			39	40
IV	65	63	M	M	30	30	37	20	61	50			M	M
V	42	38	17	15	25	28	31	35	55	65			M	M
Average	63.6	63.2	15.0	12.8	27.8	28.8	33.4	22.0	48.6	49.4			39.7	39.3
Standard Deviation	22.6	25.6	7.7	5.9	6.1	7.2	6.5	11.5	15.6	15.8			10.0	1.2

M - plant mortality

blank - no planting

Table 7.1-6. Plant cover estimates using a .25 m^2 grid for the south soil trench plants, basin plantings, north soil trench plants and flat plantings. Anvil Points, Colorado. June 1982, October 1982.

Replication	Fourwing Saltbush June	Fourwing Saltbush October	Shadscale June	Shadscale October	Cuneate Saltbush June	Cuneate Saltbush October	Western Wheatgrass June	Western Wheatgrass October	Greasewood June	Greasewood October	Prostrate Kochia June	Prostrate Kochia October	Seepweed June	Seepweed October
SOUTH SOIL TRENCH COVER														
I	31	32	M	M	19	28	31	25	56	28	M	M		
II	31	28	6	5	M	M	50	32	56	50			M	M
III	19	25	2	2	19	28	13	25	19	19	44	57		
IV	38	44	3	5	19	19	9	25	28	28			1	2
V	68	44	5	6	25	32	3	25	27	19	M	M		
VI	3	4	2	3	23	28	6	31	26	16			2	6
VII	14	16	1	2	14	19	19	50	25	32	9	9		
VIII	14	32	1	1	M	M	8	32	34	38			3	2
IX	14	19	M	M	24	32	31	19	18	25	6	9		
X	19	16	4	3	23	28	9	6	39, 25	25, 25	6	6	M	M
Average	25.1	26.0	3.1	3.4	20.8	26.8	17.9	27.0	32.6	27.7	16.3	20.3	1.7	3.7
Standard Deviation	18.3	12.7	1.3	1.3	3.7	5.1	15.0	11.1	13.0	9.7	18.6	24.5	0.6	2.1
BASIN PLANTINGS														
I	26	25	M	M	25	25	7	5	14	25			M	M
II	44	69	M	M	M	1	6	6	25	25			M	M
III	20	25	M	M	M	M	4	6	22	25			4	M
IV	63	88	M	M	M	1	3	5	24	32			M	M
V	6	M	M	M	M	M	M	M	1	M			M	M
Average	31.8	51.8	M	M	25.0	9	5.0	5.5	17.2	26.8			4.0	M
Standard Deviation	22.1	51.8			--	13.9	1.8	0.6	10.0	3.5			0.1	

Table 7.1-6. (Cont.)

NORTH SOIL TRENCH

Replication	Fourwing Saltbush June	Fourwing Saltbush October	Shadscale June	Shadscale October	Cuneate Saltbush June	Cuneate Saltbush October	Western Wheatgrass June	Western Wheatgrass October	Greasewood June	Greasewood October	Prostrate Kochia June	Prostrate Kochia October	Seepweed June	Seepweed October
I	25	28	9	6	23	32	19	25	31	28	M	M		
II	19	19	3	2	44	50	25	32	44	50			M	M
III	13	13	5	6	26	50	14	25	16	19	M	M		
IV	14	16	M	M	M	M	31	25	31	28			M	M
V	9	6	3	5	19	19	19	25	19	19	4	6		
VI	19	19	3	3	16	19	25	32	16	16			1	M
VII	4	5	3	3	16	19	26	50	28	32	14	19		
VIII	20	41	3	6	19	25	14	32	31	28			2	5
IX	13	23	3	6	26	38	16	19	26	25	M	M		
X	8	19	2	3	26	38	6	6	26	25	4	6	M	M
XI									29	25				
Average	14.4	18.9	3.8	4.4	23.9	32.2	17.7	25.1	27.0	27.7	7.3	10.3	1.5	5.0
Standard Deviation	6.4	10.5	2.1	1.7	8.6	12.6	6.4	13.2	8.1	9.7	5.8	7.5	0.7	--
					FLAT PLANTINGS									
I	7	9	3	3	6	9	1	6	4	3			5	6
II	26	44	2	1	13	19	2	3	4	3			13	13
III	19	25	9	9	24	25	2	3	8	9			6	9
IV	13	25	M	M	16	19	1	1	17	19			M	M
V	7	13	6	6	31	50	1	1	19	19			M	M
Average	14.4	23.2	5.0	4.8	18.0	24.5	11.4	2.8	10.4	10.6			8.0	9.3
Standard Deviation	8.2	13.6	3.2	3.5	9.7	15.4	0.5	2.0	7.2	8.0			4.4	3.5

M - plant mortality

blank - no planting

Table 7.1-7. Height and cover for plantings for the Soil-Shale Micro-Environment Study - Anvil Points, Colorado, June 1982.

Replication	Fourwing Saltbush 1	Shadscale 2	Cuneate Saltbush 3	Western Wheatgrass 4	Mat Saltbush 5
			Height (cm)		
I	68	19	13	25	12
II	M	22	14	35	14
III	47	23	16	23	8
IV	M	21	19	20	11
V	44	19	18	23	M
Average	53.0	20.8	16.0	25.2	11.3
Standard Deviation	13.1	1.8	2.5	5.8	2.5
			Cover (%)		
I	25	9	2	1	8
II	M	6	8	5	9
III	8	8	26	1	2
IV	M	6	31	1	5
V	13	6	25	1	M
Average	15.0	7.0	18.4	1.8	6.0
Standard Deviation	9.2	1.4	12.6	1.8	3.2

M - plant mortality

Table 7.1-8. Height and cover estimated for the demonstration planting - Anvil Points, Colorado, June 1982.

EAST FENCE

Replication	Height (cm) Grease-wood	Fourwing Saltbush	Siberian Salt-tree	Shad-scale	Big Sagebrush	Gardners Saltbush	Cover (%) Grease-wood	Fourwing Saltbush	Siberian Salt-tree	Shad-scale	Big Sagebrush	Gardners Saltbush
I	52	74	5	24	Me	14	16	13	1	13	Me	13
II	14	27				12e	4	4				9e
III	27e	59					13e	24				
IV	25						13					
Average	29.5	53.3	5	24	M	13	11.5	12.7	1	13	M	11
Standard Deviation	16.1	24.0				1.4	5.2	10.0				2.8

SOUTH FENCE

I	19	69	42	M			4	26	1	1		
II	20e	49		7e			4e	11				
III	35	90e		M			11	19e				
IV	13	M		20			2	M				
V	32e	35					6	6				
VI	43e	M					13e	M				
Average	27.0	60.8	42	13.5			6.7	15.5	1	1		
Standard Deviation	11.4	24.0		9.2			4.4	8.8				

e - grown in soil, all other in spent shale
M - plant mortality
blank - no plantings

Table 7.1-9 . Summary of height, cover and survival of plantings at Anvil Points, Colorado, 1979-1982.

South Trench Plantings	Ave. Plant height (cm)				Ave. Plant Cover (%)			Survival (%)			
	1979	1980	1981	1982	1980	1981	1982	1979	1980	1981	1982
ATCA	27	36	56	68	5	20	26	100	100	100	100
ATCO	6	9	15	13	1	1	3	100	90	80	80
ATCU	15	18	22	29	3	12	24	100	100	100	80
AGSM	22	9	15	27	1	12	23	100	100	100	100
SAVE	25	36	63	74	5	20	30	100	100	100	100
KOPR	30	19	34	44	4	11	18	67	67	67	67
SU ssp.	17	23	24	28	1	2	3	80	60	60	60

North Trench Plantings	1979	1980	1981	1982	1980	1981	1982	1979	1980	1981	1982
ATCA	24	30	55	63	2	11	19	100	100	100	100
ATCO	7	9	16	15	1	4	4	100	90	90	90
ATCU	10	10	17	21	3	9	23	100	90	90	90
AGSM	24	10	15	32	1	14	21	100	100	100	100
SAVE	21	33	55	76	4	18	27	100	100	100	100
KOPR	16	16	33	40	2	7	9	50	50	50	50
SU spp.	16	16	24	44	1	1	3	100	40	40	20

Table 7.1-9. (Cont.)

Basin Plantings

	1979	1980	1981	1982	1980	1981	1982	1979	1980	1981	1982
ATCA	27	34	63	67	5	21	41.8	100	100	100	80
ATCO	5	9	M	M	1	M	M	100	20	0	0
ATCU	9	12	13	20	2	7	17.0	100	80	60	60
AGSM	22	23	50	46	1	2	5.3	100	80	80	80
SAVE	18	29	47	61	3	11	22.0	100	100	100	80
KOPR	31	35	45	M	3	22	M	100	40	20	0

Flat Plantings

	Height (cm)				Cover (%)			Survival (%)			
	1979	1980	1981	1982	1980	1981	1982	1979	1980	1981	1982
ATCA	28	36	60	63	2	12	19	100	100	100	100
ATCO	8	9	11	14	1	2	5	100	100	80	80
ATCU	13	15	21	28	2	9	21	100	100	100	100
AGSM	20	28	32	28	1	1	7	100	100	100	100
SAVE	18	29	40	49	2	5	11	100	100	100	100
KOPR	17	23	27	40	1	5	9	100	60	60	60

Table 7.1-9. (Cont.)

	Demonstration Study (East Fence)										
	1979	1980	1981	1982	1980	1981	1981	1979	1980	1981	1982
ATCA	23	32	34	53	2	5	13	100	100	100	100
ATCO	14	16	17	24	2	7	13	100	100	100	100
ATGA	7	10	8	13	2	4	11	100	100	100	100
ARTR	15	24	M	M	2	M	M	100	100	0	0
SAVE	22	29	26	30	2	5	12	100	100	100	100
HAHA	15	14	7	5	0	.5	12	100	100	100	100
	Demonstration Study (South Fence)										
	1979	1980	1981	1982	1980	1981	1982	1979	1980	1981	1982
ATCA	30	38	48	61	2	8	15	83	67	67	67
ATCO	15	13	12	14	2	2	6	75	75	50	50
SAVE	21	23	24	27	1	3	7	100	100	100	100
HAHA	28	30	39	72	<1	1	1	100	100	100	100
	Soil-Shale Microenvironment Study										
	1979	1980	1981	1982	1980	1981	1982	1979	1980	1981	1982
ATCA	24	34	42	53	2	6	15	100	100	80	60
ATCO	6	10	12	21	1	2	7	100	100	100	100
ATCU	10	13	10	16	2	10	18	100	100	100	100
AGSM	16	19	25	25	1	1	2	100	100	100	100
ATCOR	8	8	5	11	1	2	6	100	100	80	80

M - plant mortality
blank - no planting

mortality in the north trench and two mortalities in the south trench. Prostrate kochia and seepweed have suffered the greatest overall mortality in the two soil trenches, 67% and 60% respectively in the south trench and 50% and 20%, respectively in the north trench.

The basin plantings show the highest mortality of the different establishment techniques tested on the Anvil Points shale disposal site. Fourwing saltbush, western wheatgrass and greasewood have the highest percentage survival (80%), cuneate saltbush has 60% survival, and shadscale and prostrate kochia 0% survival.

The flat plantings and demonstration study area along the east fence have not changed since 1981. Both show high survival rates for all species except big sagebrush (0%) along the east fence and prostrate kochia (60%) in the flat plantings.

The survival of species planted along the south fence as part of the demonstration study did not change from the 1981 results. Along the south fence greasewood and Siberian salt-tree show the best survival (100%) and fourwing saltbush and shadscale the worst (67%, 50%, respectively). The soil/shale microenvironment plantings experienced a single loss of fourwing saltbush. Shadscale, cuneate saltbush and western wheatgrass still show 100% survival and mat saltbush 80%.

A summary of the data collected on the plantings at Anvil Points since 1979 is presented in Table 7.1-10. Several species have shown remarkable survival and growth under the various treatments of the species (Figures 7.1-6 and 7.1-7). Fourwing saltbush, cuneate saltbush, western wheatgrass and

Table 7.1-10. Summary of growth of plantings at Anvil Points, Colorado, 1979-1982. Numbers followed by different letters are significantly different at $\alpha \leq .05$ as tested by ANOVA and Student Newman Keuls (SNK) mean separation test.

Comparison of Average
Height (cm) and Cover of Plantings
in South Trench

		1979	1980	1981	1982	F ratio
Fourwing Saltbush	HT	26.7^{a}	35.6^{a}	56.3^{b}	66.6^{b}	16.50**
	CVR	----	5.4^{a}	20.0^{b}	25.1^{b}	6.88**
Shadscale	HT	5.8^{a}	9.1^{ab}	13.8^{c}	13.6^{bc}	6.65**
	CVR	----	0.8^{a}	1.4^{a}	3.0^{b}	8.39**
Cuneate Saltbush	HT	14.6^{a}	18.0^{ab}	22.2^{bc}	27.5^{c}	6.27**
	CVR	----	2.86^{a}	11.6^{b}	20.8^{c}	66.50**
Western Wheatgrass	HT	22.3^{a}	18.8^{ab}	15.0^{b}	29.0^{c}	16.20**
	CVR	----	0.8^{a}	5.7^{a}	17.9^{b}	10.20**
Greasewood	HT	24.6^{a}	35.9^{a}	62.7^{b}	71.0^{b}	18.30**
	CVR	----	4.7^{a}	19.9^{b}	32.1^{c}	16.30**
Prostrate Kochia	HT	29.8^{a}	19.5^{a}	34.0^{a}	36.0^{a}	1.29^{ns}
	CVR	----	3.5^{a}	12.7^{a}	16.3^{a}	1.00^{ns}
Seepweed	HT	17.3^{a}	19.5^{a}	24.0^{ab}	30.3^{b}	3.51**
	CVR	----	1.0^{a}	1.8^{a}	2.0^{a}	1.41^{ns}

** F-ratio significant at $\alpha \leq .01$

Table 7.1 -10. (Cont.)

Comparison of
Average Height (cm) and Cover
of Plantings
in
North Trench

		1979	1980	1981	1982	F ratio
Fourwing Saltbush	HT	24.1^{a}	29.9^{a}	54.7^{b}	60.8^{b}	18.79**
	CVR	---	2.4^{a}	10.7^{b}	14.4^{b}	10.92**
Shadscale	HT	7.5^{a}	9.4^{a}	16.4^{b}	15.7^{b}	8.53**
	CVR	---	0.7^{a}	1.5^{a}	3.8^{b}	13.80**
Cuneate Saltbush	HT	10.3^{a}	9.8^{a}	16.8^{ab}	18.4^{b}	9.25**
	CVR	---	2.5^{a}	8.9^{a}	23.9^{b}	26.60**
Western Wheatgrass	HT	23.7^{a}	19.9^{ab}	15.0^{b}	33.0^{c}	27.70**
	CVR	---	0.7^{a}	7.0^{b}	17.7^{c}	49.20**
Greasewood	HT	21.0^{a}	33.1^{a}	55.3^{b}	75.8^{c}	27.60**
	CVR	---	4.3^{a}	18.4^{b}	27.0^{c}	35.50**
Prostrate Kochia	HT	14.8^{ab}	16.0^{ab}	32.5^{bc}	38.0^{c}	3.36*
	CVR	---	1.9^{a}	7.5^{a}	7.3^{a}	1.24^{ns}
Seepweed	HT	16.3^{a}	16.0^{a}	23.5^{a}	30.0^{a}	1.22*
	CVR	---	0.9	1.0	1.5	0.65^{ns}

Table 7.1 -10. (Cont.)

Comparison of
Average Height (cm) of
Flat Plantings

		1979	1980	1981	1982	F ratio
Fourwing	HT	27.8^{a}	36.6^{ab}	60.0^{c}	63.6^{bc}	5.41**
Saltbush	CVR	---	2.3^{a}	11.6^{b}	14.4^{b}	4.72**
Shadscale	HT	7.6^{a}	9.2^{a}	8.8^{a}	12.0^{a}	$.45^{ns}$
	CVR	---	0.9^{a}	1.3^{ab}	4.0^{c}	3.10**
Cuneate	HT	12.8^{a}	15.2^{ab}	20.6^{b}	27.8^{c}	8.95**
Saltbush	CVR	---	1.8^{a}	8.6^{a}	18.0^{b}	7.58**
Western	HT	19.6^{a}	28.2^{b}	32.2^{b}	33.4^{b}	5.06**
Wheatgrass	CVT	---	0.5^{a}	1.2^{ab}	1.4^{b}	3.43**
Greasewood	HT	18.0^{a}	28.4^{ab}	34.4^{ab}	43.8^{b}	3.43**
	CVR	---	1.9^{a}	4.6^{ab}	10.4^{b}	4.43**
Seepweed	HT	17.4^{a}	14.0^{a}	16.2^{a}	23.8^{a}	$.37^{ns}$
	CVR	---	0.8^{a}	2.8^{a}	4.8^{a}	1.59^{ns}

Table 7.1 -10.(Cont.)

Comparison of
Average Height (cm) and Cover
of
Basin Plantings

		1979	1980	1981	1982	F ratio
Fourwing	HT	27.2^{a}	33.8^{a}	63.0^{b}	65.0^{b}	15.53**
Saltbush	CVR	---	4.6^{a}	19.0^{ab}	41.4^{b}	3.32**
Shadscale	HT	5.2^{a}	1.8^{b}	0^{b}	0^{b}	6.20**
	CVR	---	.2	0	0	1.00^{ns}
Cuneate	HT	9.0	9.6^{a}	7.8^{a}	4.8^{a}	$.43^{ns}$
Saltbush	CVR	---	3.6^{a}	3.0^{a}	5.0^{a}	$.10^{ns}$
Western	HT	22.0	18.8^{a}	40.2^{a}	40.6^{a}	2.05^{ns}
Wheatgrass	CVR	---	$.4^{a}$	1.5^{a}	4.0^{b}	5.88**
Greasewood	HT	18.2^{a}	28.4^{ab}	47.0^{bc}	56.2^{c}	6.49**
	CVR	---	2.7^{a}	11.3^{ab}	17.2^{b}	4.85**
Seepweed	HT	31.2	14.0^{a}	9.0^{a}	8.2^{a}	1.88^{ns}
	CVR	---	1.1^{a}	4.4^{a}	$.8^{a}$	$.58^{ns}$

Figure 7.1-6. South soil trench plantings at Anvil Points, Colorado. Photo taken October 1982.

Figure 7.1-7. South soil trench plantings at Anvil Points, Colorado. Photo taken October 1982.

greasewood have shown the best survival and growth of the species used in the several different studies conducted at Anvil Points. Other species such as Siberian salt-tree and gardner's saltbush have shown good survival, but have not been tested as extensively as the other species. Big sagebrush and seepweed have shown the poorest survival.

B. Elemental Analysis of Plants Grown on the Shale Disposal Pile at Anvil Points. Plant tissue samples from Anvil Points were analyzed for their content of nine potentially toxic elements: arsenic, As; boron, B; cadmium, Cd; calcium, Ca; magnesium, Mg; mercury, Hg; molybdenum, Mo; sodium, Na; and sulfur, S (Table 7.1-11). The tolerance of native species to these elements has only been documented on specific isolated studies, essentially not applicable to this situation. For these reasons, only general interpretations for plant growth are available.

1. Arsenic Arsenic is ubiquitously present throughout the natural environment in trace amounts at an average of 5 ug g^{-1} (ppm) in the upper lithosphere. In soil systems, it resembles phosphorous, commonly found as a fixed form in the iron, aluminum, and calcium soil fractions.

Plants or processed food from plants rarely contain more than 1 ppm arsenic. The roots of plants are severely affected by arsenic before it accumulated in the tops to any extent. Historically, fruit trees, alfalfa, and barley have only experienced problems when arsenic levels exceeded 2.0 ppm. No data present in the literature suggests that arsenic levels found in the plant tissue at Anvil Points (0.7 ppm) would be potentially toxic to plant growth.

Table 7.1-11. Elemental analysis of tissue from plants growing on the shale disposal pile at Anvil Points, Colorado.

Species	Sample Site	As (ppm)	B (ppm)	Ca (%)	Cd (ppm)	Mg (%)	Mo (ppm)	Hg (ppm)	Na (%)	S (%)
Western Wheatgrass	South Trench	<0.1	<2	0.380	0.3	0.200	22	<5	0.078	0.18
	Basin	<0.1	<2	0.240	0.4	0.185	23	<5	0.059	0.50
	Flat	0.1	17*	0.400	0.4	0.220	23	<5	0.104	0.24
Fourwing Saltbush	South Trench	<0.1	<2	0.190	0.5	1.22	8	<5	0.088	0.25
	Basin	0.2	<2	0.320	0.2	1.13	13	<5	0.074	0.33
	Flat	0.7	4	0.430	0.4	1.05	13	<5	8.80*	0.39
Gardners Saltbush	South Trench	<0.1	2	0.310	0.4	0.760	6	<5	10.73*	0.37
	Flat	<0.1	5*	0.250	0.3	1.38	8	<5	0.445	0.52
Prostrate Kochia	South Trench	<0.1	<2	0.660	0.2	0.550	12	<5	1.52	0.99
Greasewood	South Trench	<0.1	2	0.135	0.4	0.445	6	<5	7.75	0.12
	Basin	0.2	<2	0.115	0.4	0.700	10	<5	7.75	0.29
	Flat	0.3	2	0.650	0.8	0.730	7	<5	9.80*	0.22

*Level potentially inhibitory to plant growth

2. Boron In plant nutrition, the tolerance range between deficiency and toxicity of boron for plants is very narrow. Although the tolerance range of an individual plant may be narrow, the amount of boron required by different species varies. For example, a particular concentration level of boron may be inadequate for one species and toxic for another. Because of the high solubility of boron in the soil, the concentration of boron in the saturation extract can be used to evaluate its toxicity to plants. Potentially hazardous levels of boron in plant tissues occupy an extremely wide range. In the intermountain west, 5 ppm boron in soils is the accepted level at which toxicity may occur. Two samples, western wheatgrass and garder saltbush, in the flat plantings may exhibit boron toxicity. Examinations of soil levels of boron near these two locations should be investigated further.

3. Calcium Plants that are able to grow and develop on calcareous soils are called calcicoles. The species tested for this study all fall under this classification. Tolerance to calcium is usually discussed in terms of a species' salt tolerance. The stress produced in the plant is usually not due to the primary calcium stress, but to the secondary stresses induced by the calcium. From a management standpoint, soil mitigation of any calcium-related problems would be impractical, thus species selection for stress tolerance is already an accepted practice in this program.

4. Cadmium The cadmium concentration in plants is usually about 0.3 ppm, with a range of from 0.01 to 7 ppm in soils. A number of crop plants have been shown to be capable of accumulating cadmium. LeVitt (1980) quotes

the minimum toxic levels of cadmium for Quercus rubra to be 5-30 ppm (foliar concentration). Cadmium toxicity is usually assessed by its capability to accumulate in the soil-plant-animal-man food chain. McBride et al., (1981) found the maximum quantity of cadmium absorbed in soils has been correlated with organic matter content and cation exchange capacity, suggesting that Cd^{2+} ions are returned by ion exchange and complexation. He also states that the efficiency of cadmium removal from the soil by the plants varies widely from about 1 to 28%, with plants grown in fine-textured soils having the lowest efficiencies of uptake. This knowledge and recognizing the chemical similarities between Cd^{2+} and Ca^{2+} leads us to the belief that Cd^{2+} toxicity should not be considered a significant problem at this level of analyses.

5. Magnesium Interpretations for magnesium are similar to those for calcium, being primarily expressed as salt tolerance. Magnesium toxicity to the species tested has not been cited in the literature as a focal point for growth-related problems.

6. Mercury Most vascular plants are highly resistant to mercury. Little is known regarding the toxicity of mercury to specific species, however, the extremely low (5 parts per billion) levels found in the analysis of Anvil Points plant tissues provide no cause for any hazards to be suspected.

7. Molybdenum Molybdenum is an essential element for bacteria, plants, and animals. It is required for nitrogen fixation by Azotobactor and nitrate utilization in higher plants. Molybdenum excess or toxicity in plants is rarely, if ever, observed in the field. Most plants appear to tolerate

relatively high tissue concentrations (375 ppm) without apparent toxicity symptoms. The critical level for molybdenum deficiency (0.5 ppm or lower) is about one or more magnitudes lower than the critical level of the other trace elements. The levels of molybenum found in the Anvil Points tissue analyses, ranging from 6 to 23 ppm are well within safe ranges for plant uptake.

8. Sodium Plant tissue analysis for sodium shows total percentages from 0.07 to 10.3. All of the species analyzed are proven halophytes, or plants which can grow in the presence of high concentrations of sodium salts. Furthermore, their mechanisms of salt tolerance allow large accumulations of sodium within plant tissues. LeVitt (1980) offers an extended treatise on the mechanisms of sodium resistance, salt tolerance, and acceptable levels of exchangeable soil sodium. Visual observations of healthy stands of plants at Anvil Points suggest only a minor potential for sodium toxicity existing in the form of soil reserves. No major hazards exist at the present levels of appraisal.

9. Sulfur As expected levels of sulfur existing in the soil primarily as bound SO_4^{2-} ions, complexed with sodium, calcium, and to a lesser extent magnesium are low. Plant tissue levels range from 0.12 to 0.99 percent, falling well below any toxic levels. Additions of sulfur would prove beneficial to the soil by acidification, yet as observed above, the Anvil Points plantings are vigorous and presently in no need of costly soil ammendments.

C. Pilot Model-Plant Survival and Growth on Union and Paraho Processed Shale. Disposed shale from two processes, Paraho and Union, were compared in

the pilot model with plants growing in a topsoil filled trench at the Section 6 study site. In the fall of the sixth growing season (1982) 70% of the species planted were still surviving in the portion of the pilot model containing the Union processed shale while only 50% were surviving in the Paraho processed shale. Percent survival of each species in the pilot model containing the Paraho processed shale was: fourwing saltbush, 50%; prostrate summer cypress, 100%; cuneate saltbush and Russian wildrye grass, 50%; and mat saltbush, 0%. Survival for the Union processed shale was: fourwing saltbush, cuneate saltbush, and Russian wildrye, 100%; prostrate summer cypress, 50%; and mat saltbush, 0%. Data on survival since planting are shown in Table 7.1-12.

7.1.4.5 Microbiology and Stabilization of Topsoil Storage Pile.

A. Microbiology of Stockpiled Topsoil. Long-term stockpiling can reduce microbial activities in topsoils making them less suitable as plant growth media (Rives *et al.*, 1980; Williams *et al.*, 1981). Many soil microorganisms are directly or indirectly dependent on living plants for their existence, and the absence of plant roots in much of the stored soil is partly responsible for the loss of these organisms. Soil microbial populations in stockpiles could be maintained to some extent by minimizing the duration of storage, and/or by establishing and maintaining appropriate plant cover on the storage piles. Therefore, seeding of soil stockpiles is not only valuable for erosion control and stockpile stabilization, but also for the maintainance of important soil biological characteristics. The purpose of this study was to evaluate the effect of seeding on the microbiological

Table 7.1-12. Survival and Growth of Plants in the Topsoil Trench of the Oil Shale Disposal Pilot Model. Data are from single plants over a six year period. Date of planting - April 4, 1977.

	Paraho Process				Union Process			
	A[1]		B		C		D	
Species	Rating[2]	Height	Rating	Height	Rating	Height	Rating	Height
		cm		cm		cm		cm
Kochia prostrata								
June, 1977	2	20	2	30	2	28	2	30
June, 1978	2	29	2	37	2	42	2	36
Sept., 1978	1	22	2	39	2	55	2	56
June, 1979	2	55	2	47	2	46	2	52
Sept., 1979	2	55	2	57	2	73	2	72
June, 1980	2	30	1	20	2	25	2	30
Oct., 1982	2	--	1	--	0	--	2	--
Mat saltbush								
June, 1977	2	5	2	5	2	6	2	2
June, 1978	0	0	0	0	2	18	2	5
Sept., 1978	0	0	0	0	2	20	2	2
June, 1979	0	0	0	0	2	16	1	5
Sept., 1979	0	0	0	0	2	17	1	5
Juen, 1980	0	0	0	0	2	15	1	4
Oct., 1982	0	--	0	--	0	--	0	--
Fourwing saltbush								
June, 1977	2	43	2	62	2	51	2	37
June, 1978	2	47	2	53	2	75	2	64
Sept., 1978	2	41	1	45	2	83	2	67
June, 1979	1	52	2	45	2	62	2	55
Sept., 1979	2	50	2	45	2	76	2	90
June, 1980	2	45	2	40	2	70	2	80
Oct. 1982	2	--	0	--	2	--	2	--

Table 7.1-12. (Cont.)

Species	Paraho Process				Union Process			
	A[1]		B		C		D	
	Rating[2]	Height	Rating	Height	Rating	Height	Rating	Height
		cm		cm		cm		cm
Cuneata saltbush								
June, 1977	2	8	2	7	2	6	2	5
June, 1978	2	34	2	21	2	32	2	17
Sept., 1978	1	32	2	20	2	32	2	22
June, 1979	0	0	2	20	2	30	2	20
Sept., 1979	0	0	2	22	2	23	2	22
June, 1980	0	0	2	25	2	20	2	20
Oct. 1982	0	--	2	--	2	--	2	--
Russian wildrye grass								
June, 1977	2	6	2	11	2	11	2	12
June, 1978	0	0	2	66	2	70	2	51
Sept., 1978	0	0	1	217	2	77	2	22
June, 1979	0	0	1	35	2	30	2	27
Sept., 1979	0	0	2	15	2	18	2	26
June, 1980	0	0	2	30	2	30	2	30
Oct., 1982	0	--	2	--	2	--	2	--

1/ A - Control
B - Surface stabilized
C - Control
D - Surface stabilized

2/ Rating 0 = dead
1 = poor to fair vigor
2 = good to excellent vigor

activity of stockpiled topsoil after one year of storage.

An experimental stockpile was formed at the Section 6 site in October of 1981. The pile was seeded as described in part B of this section. In October of 1982, the stockpile was sampled by drilling three 2 m deep cores on each half of the pile. Half liter soil samples were collected at each of three depths (0-30 cm, 60-90 cm, and 180-210 cm), for a total of 18 samples from the pile. Three randomly placed cores were taken on adjacent undisturbed soil within 50 m of the pile. Samples were evaluated for total organic carbon, total bacteria, total fungal hyphae length, respiratory activity, dehydrogenase activity, pH, electrical conductivity and percent moisture using methods described in the Environmental Monitoring Manual.

Populations of vesicular arbuscular mycorrhizal (VAM) fungi, important microbial symbionts of most arid land shrubs, were determined by a most-probable-number (MPN) bioassay (Seligman and Michey, 1964; Parter, 1979; Moorman and Reeves, 1979). This assay incorporated a five-fold dilution series with five replications per treatment, for a total of 625 individual replications. Infectivity of the soils was judged by microscopic examination of Melilotus officinalis roots which were grown for 12 weeks in diluted soils in 50 cm^3 Leach Tubes[R] in the greenhouse. Plants were fertilized twice at one-month intervals with half-strength Hoagland's solution with tenth-strength phosphate. They were watered as needed. This method yields a quantitative index of the number of VA mycorrhizal propagules per g of soil. Results of all tests were subjected to one-way analysis of variance (with seeding treatment and sample depth as the independent variables) and to Pearson correlation analysis

between all possible pairs of factors.

Chemical and physical properties of the soil samples are shown in Table 7.1-13. Soil moisture levels in the stockpile were comparable to those in surrounding undisturbed soils, and were certainly capable of supporting microbial activity at the time of sampling. Recent rains had wet the pile to a depth of about 35 cm. Percent soil moisture was thus negatively correlated with depth in the stockpile (Table 7.1-14). Soil pH did not vary substantially throughout the pile, nor was pH significantly correlated with any biological parameter. The pH was negatively correlated with electrical conductivity (EC) as it was in the 1981 WRS Soil Microbiology Monitoring Study. It is not clear why this is so. EC was significantly lower in the surface soils of the pile than in the deeper layers (Table 7.1-15), probably due to leaching of mineral salts by rainfall percolations (Gee and Bauer, 1976).

Soil biological properties of the stockpile are summarized in Table 7.1-15. Results of correlation analysis are given in Table 7.1-14. Dehydrogenase activity (an indicator of overall biological activity) was lower at greater depths in the pile, probably due to the relatively limited availability of oxygen and water. Dehydrogenase activity was negatively correlated with electrical conductivity (Table 7.1-14), indicating either that soil solution salts were inhibiting microbial activity, or that both EC and microbial activity were independently influenced by a third factor, e.g., water content. Dehydrogenase activities were higher in samples with high bacteria counts, but this relationship was not significant at $\alpha \leq .05$ level. There were no large differences in activity between seeded and unseeded halves of the pile. In

Table 7.1-13. Chemical and biological characteristics of soils from the WRS experimental topsoil stockpile. Cores 1-3 are from the eastern (seeded) half of the pile. Cores 4-6 are from the western (unseeded) half of the pile. Cores 7, 8 and 9 are from undisturbed soil near the pile.

Core#	Sample Depth (cm)	Moisture (%)	pH	EC (mmhos/cm)	Organic Carbon (%)	Fungal Hyphae Length(m/g)	Bacteria (10^6 CFU/g)	Respiration (10^{-4} meq) (CO_2/g·hr)	Dehydrogenase activity (mg formazan/L)	VAM (mpn/g)
1	0	11.3	9.1	0.30	0.75	26	1.74	4.3	2.8	.14
	60	4.7	8.9	0.63	0.89	13	2.17	4.0	2.4	.03
	180	5.4	9.0	0.46	0.68	28	8.57	4.7	1.2	.04
2	0	11.5	8.9	0.48	0.46	24	2.48	2.0	4.5	.35
	60	5.2	9.3	0.52	0.38	30	3.38	1.9	4.4	.30
	180	7.2	8.8	0.72	0.68	10	2.56	0.6	2.7	.03
3	0	11.7	9.4	0.36	0.60	29	2.47	3.5	5.0	.10
	60	3.8	8.9	0.61	1.11	16	4.04	6.9	4.9	.16
	180	5.7	9.4	0.70	0.82	20	2.60	7.1	2.7	.10
$\bar{x} \pm S$		7.4±3.21	9.1±.23	0.53±.15	.71±.22	21.8±7.4	3.33±2.07	3.89±2.20	3.4±1.33	.14±.12
4	0	11.1	9.1	0.39	0.74	18	3.20	3.6	3.9	0.21
	60	6.0	9.4	0.29	0.89	20	31.13	3.6	6.3	0.31
	180	6.7	9.3	0.51	1.19	15	1.56	0.9	1.4	0.01
5	0	11.1	9.1	0.33	0.75	32	2.46	4.9	4.9	0.50
	60	4.0	9.2	0.35	0.97	15	8.93	0.0	4.8	0.29
	180	4.6	9.1	0.43	0.97	12	1.82	0.0	6.0	0.50
6	0	10.6	9.2	0.38	0.60	11	2.13	0.0	5.3	0.60
	60	4.5	8.7	0.62	1.19	19	12.70	0.3	5.3	0.08
	180	10.6	8.9	0.58	0.97	39	2.61	2.5	1.6	0.10
$\bar{x} \pm S$		7.7±3.11	9.1±.21	.43±.11	0.92±.20	20.1±9.38	7.39±9.69	1.76±1.92	4.39±1.78	0.29±.21
7	0	12.8	8.5	0.15	0.53	29	1.94	4.5	1.7	(0.35)
	60	4.2								0.07
	180	5.7								0.00
8	0	12.7	9.5	0.34	0.68	17	1.86	6.5	3.0	(0.07)
	60	4.2								0.01
	180	4.5								0.00
9	0	12.4	8.7	0.37	0.51	21	1.82	7.1	3.2	(0.21)
	60	4.5								0.08
	180	4.7								0.00
$\bar{x} \pm S$		7.30±4.02	8.9±0.53	0.29±0.12	.57±0.09	22.3±6.11	1.87±0.06	6.0±1.36	2.63±0.81	(.21±0.14)

Table 7.1-14. Correlation coefficients linking the biological and chemical characteristics of soil samples from the WRS experimental topsoil stockpile. Only relationships for which $p \leq 0.05$ are listed.

	Moisture	pH	EC	Total Fungi	Total Bacteria	Respiration	Dehydrogenase	Organic C	MPN	Depth	EW
Moisture			-.42	.44				-0.48		-0.48	
pH			-0.52								
EC	-.42	-.52					-.43		-0.54	0.55	
Total Fungi	.44										
Total Bacteria											
Respiration											0.48
Dehydrogenase			-.43						0.69	-0.53	
Organic C	-.48										-.47
MPN			-0.54				0.69			-.41	-.43
Depth	-0.48		0.55				-0.53		-0.41		
EW						0.48		-0.47	-0.43		

Table 7.1-15. Influence of sample depth and location (east vs. west) on characteristics of stockpiled topsoil. Only those relationships for which $\alpha \leq .05$ are shown.

Characteristics	Variable	Treatment	$\bar{X} \pm S$
Electrical Conductivity (mmhos/cm)	Depth	0-30 cm	0.37 ± .06
		60-90 cm	0.50 ± .15
		180-210 cm	0.57 ± .12
Soil Moisture (%)	Depth	0-30 cm	11.20 ± .40
		60-90 cm	4.70 ± .82
		180-210 cm	6.68 ±2.11
Dehydrogenase activity (mg formazan/L)	Depth	0-30 cm	4.41 ± .92
		60-90 cm	4.67 ± 1.31
		180-210 cm	2.59 ± 1.77
Respiration (10^{-4} meq CO_2/g · hr)	Seeded vs Non-seeded	non-seeded	1.76 ± 1.92
		seeded	3.89 ± 2.20
Organic carbon (%)	Seeded vs Non-seeded	non-seeded	0.92 ± .20
		seeded	0.71 ± .22
Mycorrhizal Fungi (mpn/g)	Seeded vs Non-seeded	non-seeded	.29 ± .21
		seeded	.14 ± .12

fact, there were no substantial differences in plant cover between seeded and unseeded halves of the stockpile. Erosion of the pile surface was severe and most seeds were probably lost prior to germination. Pioneer species, notably Halogeton glomeratus and Bromus tectorum, did colonize the pile, but their distributions were uniform. Therefore, differences in soil characteristics between the seeded and non-seeded portions of the stockpile must be attributed to some factor other than the seeding treatment.

Soil respiration levels are another indicator of overall biological activity. Respiration in the stockpiled soil was somewhat lower than in surrounding undisturbed soils. It did not vary with depth in the pile, but it was greater in the seeded half (Table 7.1-15). The reasons for this are not clear. As previously discussed, it is not attributable to the seeding treatment.

Bacteria were most numerous at the 60 cm level, and it is thought that this represents a zone which is reached by rainfall percolation, but which does not become drastically desiccated during droughts. Populations at the surface of the pile were comparable to those of surrounding undisturbed soil and of previously sampled soils as reported in 1981. Total bacteria counts were not significantly correlated with any measured parameter.

Populations of soil fungi were positively correlated with moisture content (Table 7.1-14), another indication of the importance of soil moisture for microbial activity in an arid environment. Populations did not vary significantly with depth, nor was there any major difference betweenthe seeded and non-seeded areas of the pile.

Populations of VAM fungi (Table 7.1-15) were significantly greater

(α = .10) in the unseeded half of the pile. Again, this is not to be attributed to the seeding treatments, but is probably due to a higher content of plant material in that half of the pile. This is supported by the higher content of organic carbon in samples from that part of the pile (Table 7.1-15). Fungi survive there as spores and in root fragments in stockpiled topsoil (Rives et al., 1980), and their numbers are related to the content of organic matter included in the salvaged soil (Loree and Williams, 1981). Populations were negatively correlated with depth in the pile (Table 7.1-14,15), probably because they were maintained by the roots of plants colonizing the stockpile.

The microbial activity of the stockpile was influenced most strongly by the availability of water. Biological activities and microbial populations were greatest in those layers of the stockpile which were reached by percolating rainfall, but which were not likely to dry out during the summer months. Beyond this hydrologic influence and the apparent effect of colonizing grasses on populations of mycorrhizal fungi, no overriding chemical, physical or biological influences on the survival or activity of microbial populations were detected. After one year of storage, populations and activities were generally comparable to those of undisturbed soils in the area.

Long term storage (e.g., 3-10 years) in large stockpiles can cause changes in many of these parameters, notably in populations of mycorrhizal fungi and N_2 fixing bacteria (Cundell, 1977; Rives et al., 1980; Williams, et al., 1981). These organisms are important for seedling establishment during revegetation (Reeves et al., 1979) and it is desireable to maintain their populations during soil storage. In this experiment, populations of VAM fungi were

indeed higher in the surface layers of the pile, probably because they were maintained by roots of cheatgrass. It may be possible to maintain higher levels of microorganisms in general and VAM fungi, in particular, by establishing deep-rooting mycorrhizal plant cover on topsoil stockpiles. This is the basis of a more extensive experiment which is now in the planning stage, and which is being designed according to the procedures and guidelines established by the study reported here.

B. Seedling Establishment on Topsoil Pile and Adjacent Borrow Area. A topsoil storage pile was constructed just east of the Section 6 study site in 1981. In October of 1981, 2/3 of the storage pile was seeded with a seed mix containing 25% grasses and 75% shrubs. One half of the seeded area was raked after seeding. The other seeded portion was untreated. The other third of the storage pile that was not seeded served as a control for the experiment.

The results after the first year are reported in Table 7.1-16. The portion of the stockpile that was seeded and then raked showed the highest seedling establishment, 0.25 seedlings/m^2 in transect 1 and 1.0 seedlings/m^2 in transect 2 of sagebrush, and 0.13 seedlings/m^2 and 0.13 seedlings/m^2 of greasewood for the two transects. The area not raked but seeded, showed 0.13 seedlings/m^2 for sagebrush and 0 seedlings/m^2 of greasewood. No seedlings of seeded species were observed in the control area. The amount of annual cover was essentially the same for the three study areas on the topsoil pile.

Adjacent to and south of the topsoil pile in the borrow area, two areas one 2m x 8 m and 2 m x 11 m were seeded with the same seed mix as that used on the topsoil pile. The area 2 m x 8 m was not raked after seeding. The

Table 7.1-16. Results of seedings on topsoil storage pile Section 6, near Bonanza, Utah, October 1982.

Seed raked in

Transect 1:

Species	Plot No. 1	2	3	4	5	6	7	8	Average
ARTRW (seedling/m^2)		2							0.25
SAVE (seedling/m^2)	1								0.13
Annual Cover (%)	50	40	35	15	40	10	25	14	29
SAKA (%)	65					100			21
BRTE (%)	25	50	10	30	5		100	100	40
HAGL (%)	10	50	90	70	95				39

Transect 2:

Species	1	2	3	4	5	6	7	8	Average
ARTRW (seedling/m^2)								8	1.00
SAVE (seedling/m^2)								1	0.13
Annual Cover (%)	15	20	8	4	20	40	30	45	23
SAKA (%)									0
BRTE (%)	45	100	100	100	1	10	70	90	65
HAGL (%)	55				99	90	30	10	36

Seed Not Raked In

Species	1	2	3	4	5	6	7	8	Average
ARTRW (seedling/m^2)		1							0.13
SAVE (seedling/m^2)									0
Annual Cover (%)	60	85	60	4	4	15	20	45	37
SAKA (%)								30	4
BRTE (%)	100	90	30	100	100	100	30	10	70
HAGL (%)		8	70				70	60	26
TAOF (%)		2							0.3

Control (Not Seeded)

Species	1	2	3	4	5	6	7	Average
ARTRW (seedling/m^2)								0
SAVE (seedling/m^2)								0
Annual Cover (%)	50	20	3	8	30	85	50	38
SAKA (%)	20					10		4
BRTE (%)	40	5	100	60	15	65	85	53
HAGL (%)	40	95			85	25	13	38
CLLU (%)				40				6
TAOF (%)							2	0.3

2 m x 11 m area was raked after seeding. The area raked favored sagebrush seedling emergence, 2.5 seedlings/m^2 in comparison to 0.2 seedlings/m^2 for the unraked area. Also in the borrow area seedlings of globemallow and locoweed were found. Neither species was part of the seed mix.

7.1.4.6 Interseeding and Interplanting Existing Shrub Vegetation. As a means of increasing the wildlife carrying capacity of existing shrub dominated vegetation, interseeding and/or interplanting has been suggested. A study was established in October 1981 to test the hypothesis that scattered interplantings of container grown plants could survive and increase community diversity and productivity. A corollary hypothesis of the study tested direct seeding (drilled and broadcast) to increase diversity and productivity.

The study was established inside the Section 6 research exclosure south of the gate. Four replications, two in sites with minimal understory plants and two in areas with dense understory of cheatgrass, were seeded and transplanted. The species transplanted included gardner saltbush, fourwing saltbush, rubber rabbitbrush, and Wyoming big sagebrush (*Artemisia tridentata wyomingensis*).

The direct seeding portion of the study was accomplished by broadcast seeding followed by raking to simulate a chain drag. Drill seeding was accomplished with a hand-push single furrow seeder.

The survival and growth of the four species transplanted were observed in June and October of 1982. The results are present in Table 7.1-17 and a summary of the data in Table 7.1-18. In the areas with a heavy annual cover, only one plant of gardner saltbush, 15 fourwing saltbush and 12 Wyoming big

Table 7.1-17. Interplanting study at Section 6, near Bonanza, Utah, June and October 1982.

PLANT HEIGHT (cm)

	Site A - with annual cover								Site C - with annual cover							
	ATGA		ATCA		CHNA		ARTRW		ATGA		ATCA		CHNA		ARTRW	
Planting	June	Oct.	June	Oct.	June	Oct.	June	Oct.	June	Oct.	June	Oct.	June	Oct.	June	Oct.[1]
1	.7	M	25	M			30	14			2.5	M			13	
2			10	M			12.5	13			13	M			8	
3			2.5	M			18	14			23	M			13	
4			7.5	M							23	M			15	
5			23	M							23	M			6	
6			12.5	M							13	M			8	
7											18	M			5	
8											10	M			18	
9											8	M			15	
10																
11																
12																
13																
% Survival	8	0	46	0	0	0	23	23	0	0	69	0	0	0	69	54

Note - Upper 5 meters of the ATGA and ATCA rows of site A were washed out in Oct. of 1982

Table 7.1-17. (Cont.)

PLANT HEIGHT (cm)

	SITE B- Bareground								SITE D-Bareground							
	ATGA		ATCA		CHNA		ARTRW		ATGA		ATCA[1]		CHNA		ARTRW	
Planting	June	Oct.	June	Oct.	June	Oct.	June	Oct.	June	Oct.	June	Oct.	June	Oct.	June	Oct.[2]
1			8	8	9	M	17				11	M			5	
2			9	10	2	M	5								8	
3			2	M											15	
4			11	M			14				8	M			16	
5			13	M			13				13	M			21	
6			27	20	3	M	11		4	M					9	
7	6	M	21	M	12											
8			19	M			14									
9			13	M			10									
10	1	M	23	M	2	M	3									
11			18	M	2	M	19									
12	11	M	33	23	4	M	11									
13																
% Survival	23	0	92	31	46	0	85	77	8	0	50	0	0	0	54	77

M - Mortality

1 - Only 6 planted

2 - Height data collected but due to field entry error is not presented.

Table 7.1-18. Summary of Interplantings and Interseedings at Section 6, Near Bonanza, Utah, June & October 1982.

% Survival of Transplants

Species	Site	W/Annual Cover June	W/Annual Cover October	Site	Bareground June	Bareground October
ATGA	A	8	0	B	23	0
	C	0	0	D	8	0
AVG.		4	0		15.5	0
ATCA	A	46	0	B	92	31
	C	69	0	D	50	0
AVG.		57.5	0		71	16.5
CHNA	A	0	0	B	46	0
	C	0	0	D	0	0
AVG.		0	0		23	0
ARTRW	A	23	23	B	85	77
	C	69	54	D	54	77
AVG.		46	38.5		69.5	77

Seeding Trials

No. Seedlings/Linear M

Drilled	Site	W/Annual Cover June	W/Annual Cover Oct.	Site	Bareground June	Bareground Oct.
Grasses	A	0	0	B	2.5	0
	C	.3	0	D	0	0
AVG.		.15	0		.13	0
Shrubs	A	0	0	B	.2	0
	C	.3	0	D	0	0
AVG.		.15	0		.1	0

No. Seedlings/M^2

Broadcast	Site	W/Annual Cover June	W/Annual Cover Oct.	Site	Bareground June	Bareground Oct.
Grasses	A	0	0	B	.2	0
	C	0	0	D	0	0
AVG.		0	0		.1	0
Shrubs	A	0	0	B	0	0
	C	0	0	D	0	0
AVG.		0	0		0	0

sagebrush survived after eight months. Five months later, only 10 Wyoming big sagebrush plants appeared to be alive.

All four species survived in the bareground areas after eight months. Eleven garder saltbush, 15 fourwing saltbush, 6 rabbitbrush plants, and 18 Wyoming big sagebrush showed growth in June of 1982. By October of 1982, gardner saltbush and rubber rabbitbrush had suffered 100% mortality. Fourwing saltbush had been reduced to four plants. However, Wyoming big sagebrush had actually showed some resprouting from plants previously determined to be dead and 20 live plants were observed in October of 1982.

The low survival of rubber rabbitbrush and gardner saltbush may be attributable to the environmental conditions characteristic of the study area. However, the mortality of the fourwing saltbush and Wyoming sagebrush can be almost entirely attributable to animal damage. Figures 7.1-8 and 7.1-9 show the heavy utilization of fourwing saltbush and Wyoming big sagebrush. The plants lost between June and October of 1982 showed signs of severe grazing by rodents and rabbits, and except for a few plants lost to erosion, probably accounts for the low overall survival of fourwing saltbush especially, and to some extent, Wyoming big sagebrush.

The seeding trials both drill and broadcast on the area with annual cover showed some success in June (Table 7.1-18), but by fall no seedlings were found on any of the treatment areas. Seeding does not appear to be a viable alternative to enhance plant diversity and productivity.

The percentage of annual cover was estimated by randomly placing a quadrat 0.5 m x 0.5 m in each of the two study areas. The area designated as

Figure 7.1-8. Heavy utilization by rodents accounted for low survival of fourwing saltbush transplants used for the interplanting study at Section 6 near Bonanza, Utah.

Figure 7.1-9. Even though heavily grazed Wyoming big sagebrush showed the highest survival of the four species used in the interplanting study at Section 6 near Bonanza, Utah.

"with annual cover" was estimated to have 57% annual cover in June and 38% in October. The "bareground" area had 2% cover in June and less than 1% in October. Annual cover was exclusively cheatgrass.

7.1.4.7 Greenhouse Studies of Circular Grate Processed Shale Properties.

A. Freeze/thaw effect on physical properties of circular grate processed shale. The effect of freezing and thawing on the physical properties of circular grate processed shale was tested in the laboratory at NPI. The availability of water for plant growth is dependent on the physical characteristics of the shale, particularly texture. To test the effects of freeze/thaw cycles on particle size, ten samples of processed shale, each consisting of materials that would not pass through a 6.35 mm screen, were wrapped in several layers of cheesecloth, moistened with distilled water, and allowed to drain. The samples were then placed in a freezer at approximately -5°C for 15 hours, removed and then allowed to thaw to 20°C for nine hours, allowing for complete freezing and thawing in one 24 hour period. Each sample was moistened 2-5 times during the freeze/thaw cycle to compensate for evaporation.

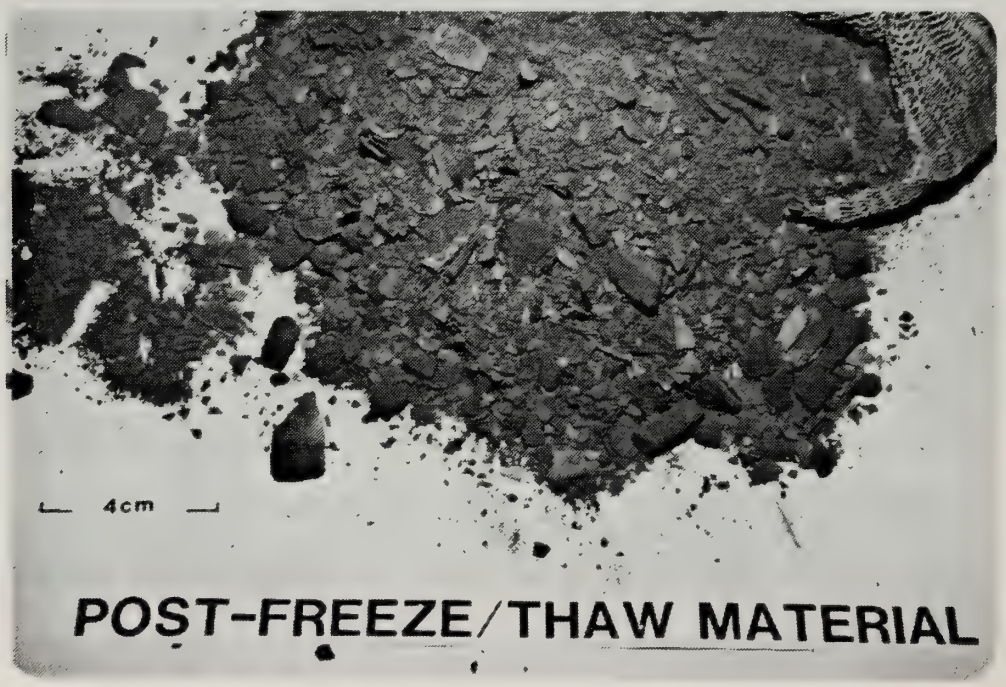
After 31 freeze/thaw cycles, the shale was removed and sampled for particle size using a standard wet sieving process (Table 7.1-19). The freeze/thaw cycles simulated in this study had a very dramatic effect on the physical structure of the shale particle size (Figures 7.1-10 and 7.1-11). Of the original shale sample over 6.35 mm in size, only 16% of it by weight did not break down into smaller particle sizes. Seventeen percent was less

Table 7.1-19. Particle size, pH and EC of processed shale before and after 31 freeze/thaw cycles. All shale particles before the freeze/thaw cycles exceeded 6.35 mm.

Sample No.	% Coarse >6.35 mm	% >2mm (#10 Sieve)	% >0.425 mm (#40 Sieve)	% >0.250 mm (#60 Sieve)	% >0.150 mm (#100 Sieve)	% >0.075 mm (#200 Sieve)	% <0.075 mm (#200 Sieve)	After Freeze/Thaw pH	After Freeze/Thaw EC	Before Freeze/Thaw pH	Before Freeze/Thaw EC
1	15	17	34	9	5	4	16	8.20	0.76		
2	18	16	34	8	5	4	15	8.19	0.81		
3	16	17	35	8	3	5	16	8.20	0.77		
4	14	17	34	9	6	4	16	8.22	0.89		
5	13	18	33	9	6	4	17	8.13	0.90		
6	17	16	33	8	5	4	17	8.18	0.85		
7	17	17	33	8	5	4	16	8.17	1.02		
8	13	17	35	9	6	4	16	8.34	0.75		
9	18	16	33	8	5	4	16	8.18	0.95		
10	20	16	32	8	5	4	15	8.32	0.54		
$\bar{X}$	16	17	34	8	5	4	16	8.21	0.82		
sd	2	1	1	1	1	1	1	0.07	0.13		
Sample 1										11.28	5.62
Sample 2										11.24	5.47
Sample 3										--	5.74
Average										11.26	5.61
Standard Deviation										.03	.14

Figure 7.1-10. Photographic display of particle size of circular grate processed shale prior to the freeze/thaw treatment.

Figure 7.1-11. Particle size comparision after 31 freeze/thaw cycles.



than 6.35 mm and greater than 2 mm. The majority (67%) was less than .425 mm, a substantial reduction from the original particle size.

In addition to wet sieving the shale samples after treatment, EC and pH were determined for the shale material prior to and after the freeze/thaw treatment (Table 7.1-19). The pH dropped from 11.26 to 8.21 and the EC from 5.61 to 0.82.

B. Leachate experiment on Circular Grate Processed Oil Shale. Leaching studies were initiated in October 1982. The purpose was to evaluate the effects of leaching on the chemical properties of circular grate processed shale, especially with regard to those water-quality parameters important for plant growth.

The predictive capability of such studies are often limited by a number of factors, which should be brought to the readers attention at the outset. Oil shales are often highly saline, highly alkaline, with sulfate ions in either the runoff or leachate (McKell et al., 1979, Schmehl and McCaslin, 1979; Ward et al., 1971). Electrical conductivity values may commonly range from 9.0 to 22.0 mmhos/cm (Schmehl and McCaslin, 1973) for processed shales evaluated as a saturation extract or 9.8 to 22.0 mmhos/cm for 1:1 extracts of Paraho processed shales. Due to complex solubility relationship existing in shale water systems, comparisons between values reported by different researchers are difficult. These are further compounded by differences in methodology, including sieving, extraction procedures, and analytical techniques.

Numerous other problems are inherent which complicate efforts to analyze

salt-release potentials of spent shale. Basically, processed shales vary widely between lithologic units and locations. They may also exhibit a wide range of properties due to variations in retort procedures including temperature and particle size of the feedstock disposal methods.

Despite these limitations, research can provide information on the quality of processed shale for plant growth. The leachate study being conducted by Native Plants will provide an ongoing assessment of the salt-release potential of the circular grate material.

In previous studies (Fransway and Wagenet, 1981) it was found that "....if an accurate laboratory assessment of water soluble salts and ions for field situations is wanted, unsieved shale should be used". For these and related practical reasons, unsieved shale material was used for this study. Furthermore, these researchers found that "the readily soluble and mobile nature of the salts, as demonstrated by the continuous ponding experiments, indicated a need to examine the behavior of these salts under conditions more reasonably approximating a field case." In their studies, large pulses of water apparently resulted in a much deeper wetting of the processed shale profiles. These findings guided our research.

Four leaching columns of approximately 120 cm in depth were packed with unsieved, circular grate processed shale to a bulk density between 1.28 and 1.40 g/cm^3. Glass wool was placed between the shale and the bottom of the column to facilitate filtering of finer shale particles transported through the leaching. Due to a limited supply of material, replications in the levels of watering were not possible. Continuous ponding with distilled water was

repeated on all four columns. At the time of the report, one pore volume of material has been leached from each column (Table 7.1-20).

The pH was determined using a 1 to 1 soil:water extract and then measured on a Corning model 125 pH meter. A saturation extract was used to measure EC and ppm of Ca, Mg, As and K was estimated using atomic absorption analysis with an ammonium acetate extractable. The sodium absorption ratio (SAR) was determined following the techniques of Richards, et al., (1954).

Analyses of the leachate from the 1st pore volume showed a substantial increase in the amount of salts present. The percentages of available calcium and potassium removed from the previously unleached shale were 90 and 89, respectively. Only 15% of the available magnesium and 18% of the available sodium were removed. The sodium absorption ratio, pH and EC of the leachate reflect the increase in the amount of available salts. Subsequent pore volumes are being leached and will be analyzed upon completion of this phase of research. Due to the limited quantity of material provided, salt release patterns as a function of the depth and time were impractical.

C. Seedling Survival and Growth on Circular Grate Processed Shale. The greenhouse transplant experiment was designed to screen various plant species for growth and survival in processed shale. The advantage to laboratory screening is that it gives quick results for relatively little cost. These results will then be useful for designing field test plot studies.

Twelve species including grasses, forbs, and shrubs (Table 7.1-21) with 20 replications were selected to monitor survival and growth in circular grate processed shale. Seedlings were transplanted with the soil plug after

Table 7.1-20. EC, pH and elemental analysis of shale and first pore volume leachate.

Leachate - First Pore Volume

Column	pH	EC (mmhos/cm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	SAR
1	7.23	4.96	75	62	1041	100	21.53
2	7.22	4.91	100	91	894	94	15.56
3	7.24	5.24	127	81	606	95	20.67
4	8.03	4.47	109	88	990	81	17.09
Average	7.43	4.90	103	81	883	93	18.71
Standard Deviation	.40	.32	22	13	194	8	2.85

Unleached Shale

Sample	pH	EC (mmhos/cm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	SAR
A	10.34	10.51	104	549	4413	105	38.24
B	10.31	10.12	120	524	5395	99	47.35
C	10.33	10.85	117	538	4980	112	43.27
Average	10.33	10.49	114	537	4929	105	42.95
Standard Deviation	.02	.37	9	13	493	7	4.56

Table 7.1-21. The growth of 12 species planted into circular grate processed shale after six weeks. Each species was replicated 20 times.

Species	Growth (mm)																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Mean
Agropyron cristatum	12	64	83	79	62	56	59	4	63	77	50	79	53	108	47	65	76	35	35	76	59
A. smithii	70	133	161	118	104	54	147	42	102	127	124	123	133	78	81	93	85	108	132	124	107
Elymus junceus	76	19	48	82	46	33	42	25	31	34	21	55	62	62	51	60	83	105	86	71	55
*Oryzopsis hymenoides**																					
*Stipa comata**	-15	21	26	2	2	2	36	-10	14	12	5	5	20	-5	11	18	18	26	24		
*Hedysarum boreale**	-12	6	-9	-3	3	-4	-3	-14	33	12	15										
*Linum lewisii**	20	28	44	39	23	8	31	13	7	34	25	34	25	41	30						
*Sphaeralcea ambigua**																					
*S. munroana**																					
*Atriplex canescens**	21	6	2	24	3	4	16	-6	14	5											
*Artemisia tridentata**	1	4	8	6	2	4	0	12	2	7	24	10	-2								
*Sarcobatus vermiculatus**																					

* Experiment in progress

the first true leaf had formed. The experiment was initiated in November 1982 and transplanting into the shale began in December 1982 and at the time of report preparation is continuing due to the various dormancy and germination requirements of each species. An individual seedling was transplanted into a 60 mm x 40 mm x 50 mm cell which contained the processed shale (Figure 7.1-12). Transplants were watered daily or every other day depending on the shale moisture content. Water volumes were small to avoid leaching. The intent of the study was to optimize all factors for growth except for the soil media which was processed shale. Any adverse growth responses could then be attributable directly to the shale, such as micronutrient deficiencies or poor root penetration. Seedling height was measured at the time of transplanting into the shale and then again after six weeks. If a seedling died it was replaced only once. After six weeks of growth in processed shale, several transplants were excavated to evaluate root growth. The roots were found throughout the shale material; some had even grown out of the bottom of the pots.

Only three species to date have completed the six week experiment. Western wheatgrass (Agropyron smithii) had 100% survival and showed an increase in growth of 107 mm. Crested wheatgrass and Russian wildrye also had 100% survival and increased growth was 59 mm and 55 mm, respectively. Although all 20 replications of needle and thread grass (Stipa comata) have not completed the six week growth period, it appears this species will have the least increase in growth (11 mm) among the grasses. No data as yet has been collected from Indian ricegrass (Oryzopsis hymenoides).

Figure 7.1-12. Example of planting flat used to evaluate seedling growth and survival in processed shale.

One forb species, blue flax (Linum lewisii) has demonstrated fairly good growth in processed shale. Blue flax has had 15 individuals complete six weeks growth in the shale, with an average growth of 27 mm. Northern sweet-vetch (Hedysarum boreale) has grown only 2 mm (average of 11 individuals) and many have lost leaves and appear to be showing micronutrient deficiences. No data has been collected from the globemallow (Sphaeralcea) to date. Seeds from this species have a long dormancy and low germination percentage, as demonstrated in the seed germination experiment.

Shrub species are generally slower growing than the grasses and forbs. Fourwing saltbush grew 9 mm (10 individuals). No data as yet has been collected on greasewood.

From observation, the grasses appeared to have normal growth and form. Blue flax appeared normal, although a few individuals shortly after the six week growth period have died and others are losing the lower leaves. Only one or two individuals of northern sweetvetch appear normal in growth and form. Many of the others show a constricting and weakening on the stem at the shale line. Big sagebrush also has shown constricting and bending at the shale surface. Fourwing saltbush appeared normal until about five weeks into the experiment when the tops began to constrict and bend over. Appearance of these plants indicated either toxicities or micronutrient difficiencies.

D. Seed Germination Study on Circular Grate Shale. The seed germination study in processed oil shale was designed to give preliminary data on species which are able to germinate under high EC and pH levels and under different soil moisture conditions. Germination tests were conducted in

Union processed shale rather than circular grate processed shale since there was not enough circular grate processed shale for all tests scheduled. Circular grate processed shale that is left from the transplant and leaching experiments will be used in a germination test during spring 1983.

Three separate oil shale germination study plots measuring 53 cm x 91 cm x 5 cm were established on July 30, 1982, outside NPI offices in Salt Lake City. Each species was sown in separate rows at a rate of 16.8 kg PLS/hectare. The plots were subjected to three different watering regimes: 13 mm water daily; 13 mm water every three days; 13 mm water every week (Figure 7.3-13). Watering amounts were intended to simulate conditions that could be expected at the Utah site. All soils were watered to field capacity to begin the testing. Germination was recorded daily for 31 days and periodically thereafter.

The species used in the experiment were:

Forbs

Hedysarum boreale
Sphaeralcea ambigua
S. munroana

Grasses

Agropyron cristatum
A. trichophorum
Elymus junceus

Shrubs

Artemisia tridentata
A. nova
Atriplex canescens
A. cuneata
Ceratoides lanata
Chrysothamnus nauseosus
Sarcobatus vermiculatus

The number of emerging seedlings of each species was recorded daily. Since the ultimate objective was to evaluate seedling survival, the first several days after emergence no seedlings were removed. The procedure,

Figure 7.1-13. Seed germination study layout at office headquarters of Native Plants, Inc.

however, made it impossible to obtain the total number of seeds germinating over the course of the experiment. What is reported is the maximum number of seeding occurring at any one day.

The number of living seedlings observed each day on the "daily watered" plot is given in Table 7.1-22. Figures are not given for the other two plots since no germination occurred on either plot.

The three study plots will be left intact for periodic observation throughout the winter and spring. Ambient temperatures and soil temperatures were observed during the 31 day trial. On August 10 the ambient high temperature was 35°C, the soil temperature of the processed shale material was 40.5°C at ½ inch depth (approximate depth of seed). Soil temperatures ranged from 2° to 9°C warmer than the ambient temperature, depending on the degree of sunshine or clouds. It was also observed that watering caused a 3° to 15°C drop in temperature when compared to non-watered plots.

7.1.4.8 Publications Resulting From Project.

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Table 7.1-22. Daily counts of germinated seedlings occurring over a 31 day period.

Date	Agcr	Agtr	Arno	Artr	Atca	Atcu	Cela	Chna	Elju	Hebo	Orhy	Save	Spam	Spmu	Stco
Aug. 4												6			
5					3							10			
9					3				18			0			
10					3				19						1
11					3				26						2
12					3				26	6			1		1
13					4				31	9			1		4
14					1				34	9	1		1		5
16					0				35	7	1		1		7
17									20	8					12
18									30	9	1		1		11
19					0				24	9	1		1		11
20									11	10					13
23									15	8	0		0		10
24									13	8					10
25									13	8					11
26															9
27									8						8
29	5								6	2				1	5
30	10					1			7	2				2	8
31	6					1			4	2				16	9
Sept. 1	13		1		1				2	2			1	19	9
2	4		2		2					2			3	20	
3	4									2			3	22	

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In addition to the above publications, the following students prepared theses on research at USU carried out on the reclamation project.

Name	Degree	Subject
Kent Crofts	M.S.	*Atriplex* seedling vigor

Name	Degree	Subject
Eduardo Alvarez	M.S.	Sagebrush propagation
Jerry Barker	M.S.	Container-grown transplants for establishment on oil shale sites
Steven Richardson	Ph.D.	Salinity tolerance of shrubs of the oil shale region
Ali Malek	Ph.D.	Water harvesting from a processed shale disposal pile
Chris Call	Ph.D.	Mycorrhizal relationships in plant establishment on processed shale

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